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(54) **Signature verification system, apparatus and document.**

(57) Signature verification systems are disclosed which include documents each of which bears a cryptographic representation of a function of a position-invariant transform of a reference signature of an authorized user thereof. On some of these documents the cryptographic representation is a digital image of a logarithmic function of the Fourier spectrum of the reference signature displayed as an intensity function the pixels of which have been recollocated in accordance with a cryptokey which is represented on the document. Apparatus (24, figure 3) are disclosed for use in producing such cryptographic representations on documents. Apparatus (36, figure 4) are disclosed for verifying documents bearing such cryptographic representations and also bearing specimens of the corresponding reference signatures. Methods of signature verification using documents bearing such cryptographic representations and specimens of said reference signatures are also disclosed.

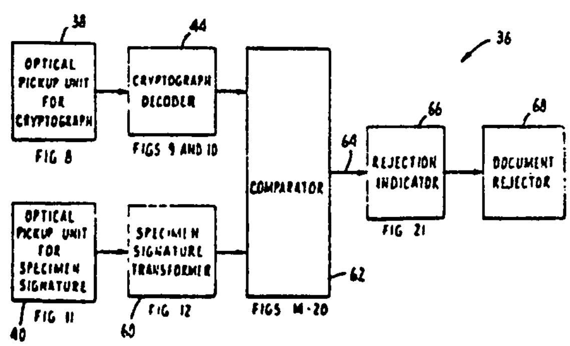

FIG. 4.

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Signature Verification Systems

The present invention relates to signature verification systems whereby to provide security in financial transactions, access to buildings and areas, and the like, and more particularly to methods and apparatus to be employed in such systems, including cryptographically encoded documents, apparatus for use in producing such documents, and apparatus for utilizing such documents in the verification of specimen signatures made by authorized users of such documents.

Methods and apparatus for the verification of handwritten signatures in order to provide security in financial transactions, access to buildings and areas, and the like are known in the prior art. Such prior art methods and apparatus are disclosed, for example, in the following United States Letters Patent: 3,676,000 (hereinafter "Mayer-Dobbins '000"); 3,781,109 (hereinafter "Mayer-Dobbins '109"); 3,178,993 (hereinafter "Ferris"); 3,166,625 (hereinafter "Brumley"), 3,955,178 (hereinafter "Warfel"), 3,620,590 (hereinafter "Barker"); 3,579,186 (hereinafter "Johnson"); 3,806,704 (hereinafter "Shinal"); and 3,643,216 (hereinafter "Greenaway").

The systems of these prior art patents suffer from one or more of the following disadvantages: (1) The document verifying devices of most of these systems are not fully automatic, or (2) the document verifying devices of these systems are not autonomous or self-contained, and thus they involve elaborate and extensive communication networks for the transmission of signature comparison data, or (3) they are holographic, and thus require that every document be provided with an inset of photographic film bearing a hologram, or (4) they do not provide any means of authenticating the signature comparison data recorded on each document (usually in cryptographic form) to determine whether the

signature comparison data on a particular document was derived from an authentic reference signature of an authorized user of the document.

As is well known to those having ordinary skill in the art, a serious need exists for fully automatic systems for both verifying and authenticating handwritten signatures of authorized users of documents such as bank checks, savings account passbooks, credit cards, identification cards, and the like, especially in the banking industry where check processing facilities are faced with the problem of examining of many thousands of checks per day, and detecting and returning fraudulent checks within a very short period of time, sometimes as little as 24 to 48 hours. It is anticipated that this burden will be considerably exacerbated in the near future, when check processing systems now under test or consideration are adopted by the banking industry. Among these systems are those now called "bulk-filing, cycle-sorting", and "check safekeeping".

Accordingly, it is an object of the present invention to provide systems for automatically verifying, or verifying and authenticating, specimen signatures on documents without the use of expensive and elaborate communication systems for conveying signature comparison data from large numbers of remote signature data storage points.

More particularly, it is an object of the present invention to provide systems for automatically verifying, or verifying and authenticating, specimen signatures on documents, in which systems the document readers or document examining devices are completely autonomous, i.e., derive all of their signature comparison information from the documents themselves, and thus require no associated data communications links or systems at all.

A further object of the present invention is to provide systems for automatically verifying, or verifying and authenticating, specimen signatures on documents, in which systems all of the necessary reference signature comparison data is directly imprinted on the documents in the form of cryptographic representations.

An additional object of the present invention is to provide systems for automatically verifying, or verifying and authenticating, specimen signatures on documents, in which systems said cryptographic representations are substantially devoid of light wave phase information, i.e., are non-holographic.

A yet further object of the present invention is to provide systems for automatically verifying, or verifying and authenticating, specimen signatures on documents, in which systems the cryptographic representation of reference signature comparison data imprinted on the documents may be readily superencrypted in one or more modes of superencryption, identified on the documents only by cryptokeys, so that information necessary to decrypt the cryptographic representations on the documents and thus learn the reference signature comparison information embodied in the crytographic representations on the documents is not available on any document, but only available in high-security data banks at document presentation points.

Another object of the present invention is to provide systems of this kind in which said cryptokeys form a part of indicia printed on the documents for identifying individual documents with authorized users thereof, such as account numbers on bank checks, whereby to render "cut-and-paste" forgeries difficult, if not impossible.

A further object of the present invention is to provide systems for automatically verifying, or verifying and authenticating, specimen signatures on documents, in which systems reference signature comparison data is reproduced on each document in the form of a representation of a function of a position-invariant transform of a reference signature of an authorized user of the document.

Yet another object of the present invention is to provide systems for automatically verifying, or verifying and authenticating, specimen signatures on documents, in which systems said cryptographic representations are digital images of enhanced Fourier spectra of reference signatures displayed as intensity functions.

Other objects of the present invention will in part be obvious, and will in part appear hereinafter.

The present invention, accordingly comprises the several steps and the relation of one or more such steps with respect to each of the others, and the apparatus, including documents, embodying features of the construction, combinations of elements, and arrangements of parts which are adapted to effect such steps, all as exemplified in the following disclosure, and the scope of the invention will be indicated in the appended claims.

In accordance with a feature of the present invention, financial documents, identification documents, and the like are provided with representations of functions of position-invariant transforms of reference signatures of authorized users thereof for use in verifying such documents when presented for acceptance.

In accordance with another feature of the present invention, one of said transforms is the Fourier transform.

In accordance with another feature of the present invention, one of said functions is the Fourier spectrum.

In accordance with another feature of the present invention, at least some of said functions are compound functions consisting of predetermined successions of component functions, the first component function of any such succession being a function of one of said position-invariant transforms, and each of the remainder of the component functions of said succession being a function of another one thereof.

In accordance with a further feature of the present invention, documents provided with representations of such compound functions of reference signatures of authorized users thereof are also provided with cryptokey indicia identifying one or more of said component functions, the thus identified component function or functions being selected as a cryptographic function or functions, and being unrepresented on said documents.

In accordance with an additional feature of the present invention, such cryptokey indicia constitutes at least part of an indicium borne by the same document which identifies the authorized user therewith.

In accordance with a particular aspect of the present invention, such an indicium identifying an authorized user with such a document may be at least part of a personal identification code designation.

In accordance with another aspect of the present invention, such an indicium identifying an authorized user with a

document may be at least part of an account code designation.

In accordance with another feature of the present invention, a method of signature verification comprises the steps of reproducing on a document a cryptographic representation of a function of a position-invariant transform of a reference signature of an authorized user thereof, and also reproducing on said document a key to said crytographic representation comprising at least one indicium.

In accordance with another feature of the present invention, such a representation on a document may be a digital image of a function of a Fourier spectrum of a reference signature of an authorized user of said document displayed as an intensity function, the pixels of which have been recollocated in accordance with a predetermined mode of transposition corresponding to a cryptokey.

For a fuller understanding of the nature and objects of the present invention, reference should be had to the following detailed description, taken in connection with the accompanying drawings.

Fig. 1A illustrates a document, viz., a bank check, incorporating certain features of the present invention;
Fig. 1B illustrates in greater detail the cryptographic representation borne by the document of Fig. 1A;
Fig. 1C shows an electrical signal corresponding to a part of such a cryptographic representation;
Fig. 2 shows an alternative form of cryptographic representation;
Fig. 3 is a schematic representation of the major subsections of a cryptograph transparency maker embodying teachings of the present invention;

Fig. 4 is a schematic representation of the major subsections of a document reader or verifier embodying teachings of the present invention;

Figs. 5 through 7 together represent an algorithm for the comparison of properties extracted from a reference signature and a specimen signature in accordance with the teachings of the present invention, which algorithm also constitutes a major part of the present invention;

Figs. 8 through 26 together constitute a schematic representation of a signature verification system embodying the teachings of the present invention; and

Fig. 27 is a diagram representing the operation of the superencryptment means of the signature verification system of Figs. 8 through 26.

Referring now to Fig. 1, there is shown a bank check 10 embodying features of the present invention.

Bank check 10 is of the type which may be produced with well-known photo offset check printing techniques and equipment by utilizing reference signature cryptograph transparencies or "cryptograph transparencies" such as may be produced from corresponding bank signature cards by means of a cryptograph transparency maker embodying the present invention, such as is shown schematically in the general block diagram of Fig. 3.

Check 10 is a check of the type adapted to be used in the check reader or verifier embodying the present invention which is schematically shown in the general block diagram of Fig. 4.

For clarity and ease of understanding the present specification, certain terminology which is sometimes used in a special manner herein will first be discussed, with parti-

cular reference to banking applications of the present invention.

The term "reference signature" as used herein denotes a signature recorded for possible future reference, e.g., a depositor's signature on a bank signature card.

The terms "specimen of said reference signature" and the like as used herein denote a signature later executed by the writer of a corresponding reference signature with the intent to execute his signature in the format of that reference signature. This definition recognizes that many persons consciously adopt two or more signature formats, e.g., one format for social transactions and another for financial transactions. Thus, if an individual has written his financial signature on a bank signature card, his later-written financial signature, executed with the intent to execute his financial signature will be "a specimen of said reference signature" in accordance with this definition, taking the financial signature on the bank signature card as the "reference signature"; but his social signature, executed with whatever intent, will not be "a specimen of said reference signature".

Further, this definition also recognizes that for sometimes subconscious or unappreciated reasons individuals change their signatures at certain times of life, gradually or precipitously. In accordance with this definition, a signature of an individual executed after such a signature change and manifesting a discernible change or changes in handwriting style or format is not a "specimen" of a reference signature executed by that individual before that change.

The term "authorized user" as that term is used herein refers to a document, such as a bank check, and denotes any

person entitled to utilize that document. Thus, a depositor in a bank checking account whose signature appears on a corresponding signature card is an authorized user of checks drawn on that account.

The term "cryptograph" is used herein in its broadest acceptation to denote any pattern or indicium whether symbolic or graphic having a hidden or not directly discernible significance, and thus embraces all of the concepts and things embraced by the term "cryptoideograph". Thus, the term "cryptograph" as used herein embraces not only modified writings having hidden significance, but also embraces modified or distorted patterns having hidden significance, such as a hologram of a handwritten signature or a mosaical anamorphosis of a handwritten signature.

The term "cryptograph" as used herein also denotes any encrypted cryptograph. Thus, not only is the Fourier spectrum of a handwritten signature produced by a Fourier transformer a cryptograph, but a mosaical anamorphosis of that Fourier spectrum is also a cryptograph, as the term "cryptograph" is used herein. In this example, the original handwritten signature can be thought of as "superencrypted" or "superenciphered".

The term "non-holographic" is used herein in its broadest acceptation to refer to any thing incapable of giving rise to a three-dimensional representation of an original object, however illuminated, or any process incapable of giving rise to such a representation when applied to a suitable thing.

It should also be noted that for ease of understanding the term "specimen signature" will sometimes be used herein in lieu of the term "specimen of said reference signature", when the context permits of no ambiguity.

Referring again to Fig. 1, it will be seen that a particular signature 12 has been handwritten or reproduced on signature 14 of bank check 10.

For the purpose of this discussion it will be assumed that specimen signature 12 is a specimen of a reference signature in the sense in which the term "specimen of said reference signature" is defined hereinabove.

In other words, it is assumed that there is in the possession of the bank on which check 10 is drawn a signature card bearing a reference signature of which specimen signature 12 is a specimen, in the sense that specimen signature 12 was executed by the writer of said reference signature on said signature card with the intent to execute his signature in the format of that reference signature.

Referring again to Fig. 1, it will be seen that bank check 10 is imprinted with a halftone pattern 16, located near the upper edge of check 10 and to the left of the line provided for manually recording the check number.

Halftone pattern 16, which will hereinafter be call~~ed the~~ "reference signature cryptograph" or "cryptograph" is discussed in detail below in connection with Figs. 1B, 1C, and 2.

It should be noted here, however, that the particular location and configuration of reference signature cryptograph 16 on check 10 is not an essential feature of the present invention, so long as the location and configuration of the reference signature cryptograph is the same on all of the checks of a particular signature verification system of the present invention.

Thus, the reference signature cryptograph on every check intended for use in the signature verification system which includes bank check 10 must be of the same configuration and located in the same position as cryptograph 16 on check 10.

In other such check verification systems, on the other hand, the cryptograph on each check might, by way of example, be located to the left of signature line 14, and directly above the MICR number found at the bottom of each check.

In another check verification system of the present invention the cryptograph might be subdivided into separate sets of four adjacent rows of halftone elements, and these sets of halftone elements colinearly arrayed, e.g., along the bottom and top edges of the check, where the additional cost of providing reading equipment for reading such linear arrays can be justififed, say, by the unavailability of sufficient check "real estate" to accommodate a single, square or rectangular, reference signature cryptograph like cryptograph 16 of bank check 10 of Fig. 1.

It is also to be understood that the reference signature cryptographs of checks to be processed in a signature verification device embodying the present invention need not necessarily be halftone prints adapted to be read by photoelectric scanning means, but rather may be magnetic recordings, e.g., superimposed magnetic recordings of the kind taught in United States Patent No. 2,989,595 issued to Jonathan Hunter on June 20, 1961. Further, such superimposed magnetic recordings may be impressed on their corresponding bank checks either by halftone printing in magnetic ink, or by magnetic recording on uniform strips of magnetic material imprinted thereon.

Further, the cryptographs of the invention may be xeroprints; of conventional type or made by xeroprinting apparatus of the kind disclosed in United States Patent No. 3,550,149, issued to Marvin Camras on December 22, 1970.

Thus, it will be understood that the location, configuration, and recording mode of the reference signature cryptographs on the checks of different signature verification systems embodying the present invention may vary widely from system to system, but must be very closely maintained the same for all of the checks or other documents of a single signature verification system embodying the present invention.

Referring again to the bank check 10 of Fig. 1A, and more particularly to the lower, left-hand corner thereof, it may be seen that bank check 10 is imprinted with a clock track 18 and an information track 20, from which can be read by automatic reading means a number which constitutes a key or cryptokey to cryptograph 16.

It is to be understood that clock track 18 and corresponding information track 20, like reference signature cryptograph 16, may be differently located and configured on the checks of different check verification systems embodying the present invention, but must be substantially identically located and configured on all of the checks of any one of the signature verification systems embodying the present invention.

Further, it is to be understood that the present invention is not limited to having cryptokey information recorded in the form of a simple bar code on two tracks, one of these tracks being a clock track.

Rather, on the checks of some check verification systems embodying the present invention the numerical value of the cryptokey may be recorded in MICR numbers, and be so located as to be readable by the same MICR reader which reads the account number, etc., conventionally recorded near the center of the lower edge of each bank check.

Other imprinted codes, both photoelectric and magnetic, may be used for recording the cryptokey data on the checks of a particular signature verification system embodying the present invention.

Referring now to Fig. 1B, there is shown a small portion of cryptograph 16 of check 10 (Fig. 1A). It is to be noted that the elements 21 of cryptograph 16 constitute "islands" of limited area, set in a non-white background 21'. Since cryptograph 16 is photographically reproduced from a cathode ray tube screen in cryptograph display unit 32 (Fig. 3) it is to be expected that it and all other cryptographs of the same system will have such a background. Such limited area "islands" will be referred to as "pixels" herein, as will the "full size" pixels of Fig. 2. Further, cryptograph 16 will be referred to as a "digital image" herein, quite as much as the digital image of Fig. 2.

Referring to Fig. 1C, there is shown an electrical signal such as would result from photoelectric scanning of one row of the insular pixels of cryptograph 16. This electrical signal will be discussed in detail hereinbelow.

Referring now to Fig. 2, there is shown a reference signature cryptograph 22 of the same type as reference signature cryptograph 16 of the bank check 10 of Fig. 1A.

Reference signature cryptograph 22 of Fig. 2 is a digital image of a logarithmic function of the Fourier spectrum of a handwritten signature displayed as an intensity function.

This digital image is of the continuous or "no-background" type which may be used in some embodiments of the present invention.

Reference signature cryptograph 22 is a 64 X 64 array of halftone pixels, each pixel imprinted at one of 16 grey levels.

Each of the pixels of reference signature cryptograph 22 may be individually identified by a pixel location code of conventional type, in which the upper left-hand pixel shown in Fig. 2 is designated by the particular (x/y) code value 0/0, the upper, right-hand pixel as shown in Fig. 2 is identified by the particular code designation 0/63, and the lower, right-hand pixel shown in Fig. 2 is identified by the particular code designation 63/63.

The insular pixels of cryptograph 16 may be identified in the same way.

In describing such reference signature cryptographs hereinafter, the terminology and conventions employed at pages 5, 6, and 21 through 31 of <u>Digital Image Processing</u>, by Rafael C. Gonzalez and Paul Wintz, published by Addison-Wesley Publishing Company, Inc., 1977, (hereinafter "Gonzalez-Wintz") will be used.

It is to be understood, however, that not all of the reference signature cryptographs found on checks of various signature verification systems embodying the present invention are unencrypted digital images of a logarithmic function of

the Fourier spectra of handwritten signatures displayed as intensity functions, as is reference signature cryptograph 22 of Fig. 2.

Thus, reference signature cryptograph 16 of Fig. 1A is not an unencrypted digital image of a logarithmic function of the Fourier spectrum of the reference signature of which specimen signature 12 is a specimen. Rather, reference signature cryptograph 16 of Fig. 1A is a "scramble", or more accurately a recollocation according to a predetermined mode of recollocation, of the pixels of a digital image of a logarithmic function of the Fourier spectrum of said reference signature displayed as an intensity function.

It is to be understood, however, that the particular systematic mode of pixel (or pixel content) recollocation employed in generating reference signature cryptograph 16 of bank check 10 of Fig. 1A is but one of a number of systematic modes of pixel recollocation which will be used in generating the reference signature cryptographs found on other bank checks of the same signature verification system embodying the present invention.

Rather, in accordance with a principal feature of the present invention, a considerable number of different modes of pixel recollocation, or pixel content recollocation, will be employed in a single system embodying the present invention, each mode being identified by a key number.

These key numbers, corresponding to respective modes of reference signature cryptograph pixel recollocation, are employed in signature verification systems embodying the present invention as cryptokeys.

That is to say, when a particular mode of pixel recollocation has been used in generating the reference signature cryptograph on a particular check, the key number or cryptokey corresponding to that particular mode of pixel recollocation is represented on that same check in machine-readable form, as by means of a simple bar code such as that of information track 20 of the bank check 10 of Fig. 1A.

Conversely, the bar code information embodied in information track 20 of check 10 is a multi-digit key number or cryptokey number, and that key number or cryptokey number is uniquely identified with the systematic method of pixel recollocation which was employed in generating reference signature cryptograph 16.

Since none of the said modes of pixel recollocation are described or set out anywhere on bank check 10, but rather are exclusively found in the check readers or check examining devices of the check verifying system of which check 10 is a part; and since, as best seen from Fig. 1B, the unrecollocated digital images themselves are sufficiently apparently random in nature so that the correct vertical order of pixel rows cannot be accurately deduced therefrom, check 10 does not provide sufficient information to enable a forger, even very extensively equipped, to reconstitute the corresponding reference signature from reference signature cryptograph 16, even assuming the forger was able to easily read the simple bar code of track 20.

It is for this reason that these systematic modes or cryptograph pixel recollocation, and the recollocated cryptographs resulting from the employment thereof, are sometimes called "cryptographic functions".

It is to be noted here that the cryptograph comparison algorithm embodied in the formulae of Figs. 5 through 7, which is a principal feature of the present invention, is particularly susceptible to simple, low order modes of cryptograph pixel recollocation, and that thus the cryptograph comparison algorithm of the invention greatly reduces the expense and complexity of the necessary cryptograph recollocation equipment necessarily embodied in the cryptograph transparency generators and check readers of check verification systems embodying the present invention.

Among the simplest of said modes of recollocating pixels to which the cryptograph comparison algorithm of the present invention is particularly sensitive is the simple mutual transposition of several pairs of pixel rows.

One such simple transposition of a pair of pixel rows might, for example, be the mutual transposition of pixel rows 25/0-25/63, i.e., row 25, and 38/0-38/63, i.e., row 38, of the cryptograph of Fig. 2.

As will be evident from the inspection of the formulae of Figs. 5 through 8, a very few of such mutual transpositions can very substantially reduce the value of the signature correlation coefficient, C_s of Fig. 7.

It is further to be understood that the above-discussed modes of pixel recollocation are by no means the only reference signature cryptograph superencryptment modes contemplated for use in embodiments of the present invention.

For example, it is contemplated that in some check verifying systems embodying the present invention the reference signature cryptographs on the checks may be superencrypted by incrementally increasing or decreasing the grey levels of the pixels of certain pixel subarrays.

As an example of this mode of cryptograph superencryptment, consider the reference signature cryptograph of Fig. 2 as a reference signature cryptograph to be thus superencrypted. This superencryptment may be carried out by increasing the grey level of every pixel in row 25 by one grey level value, and at the same time reducing the grey level of every pixel in rows 32, 54, 58, and 62 by one grey level value or grey level increment.

Other superencryptments of this same kind may be carried out by reducing the grey level of every pixel of given lines by more than one grey level interval, or increasing the grey levels of the pixels of certain rows by more than one grey level increment.

As will be evident to those having ordinary skill in the art, simple superencryptments of this kind may be carried out by, e.g., suitably biasing the control grid in a cathode ray tube used in displaying or generating a reference signal cryptograph, employing different bias levels during the sweeping or generation of different pixel rows in accordance with the predetermined superencryptment mode.

It should also be noted that given the particular cryptograph comparison algorithm used in the system embodiment shown and described herein, which algorithm is itself a particular feature of the present invention, only a relatively small number of pixel rows need be thus incremented or decremented in order to so superencrypt a given cryptograph that without suitable decryptment its overall correlation coefficient C_s will be drastically reduced as compared to the corresponding correlation coefficient C_s for comparison of the unencrypted cryptograph with the cryptograph generated from the specimen signature on the same check.

As will now be evident to those having ordinary skill in the art, informed by the above disclosure, a substantial infinity of superencryptment modes may be devised by those having ordinary skill in the art, as taught by the present disclosure, without themselves exercising invention or engaging in undue experimentation.

It is to be further understood that a document security method called "double superencryptment" is a feature of the present invention.

In accordance with the method of double superencryptment, all of the cryptographs of the checks or other documents of a particular signature verification system of the present invention are first superencrypted in the same manner, this first superencryptment being called the "basic superencryptment" or "universal superencryptment" of the particular signature verification system embodying the present invention.

Thereafter, in accordance with the principle of double superencryptment of the present invention, "keyed superencryptments" such as described are applied to the once encrypted cryptographs of certain subclasses of the documents of that signature verification system, and the documents of each class are imprinted with a unique key or cryptokey identifying the particular mode of second superencryptment employed in connection with all documents of the particular class.

An example of a document of such a doubly superencrypted check verification system is bank check 10 of Fig. 1A.

In that case all of the checks of that check verification system bearing the same bar code 20 would constitute a

single class, and the keyed superencryptment would be the same for the cryptographs found on every check of that class in that system.

Typically, then, cryptograph 16 of Fig. 1 might be thought of as a compound function of the corresponding reference signature, of which signature 12 is a specimen.

In generating reference signature cryptograph 16 a Fourier transformer would first be used to produce a Fourier spectrum of the reference signature, displayed as an intensity function.

This Fourier spectrum intensity function could, of course, be thought of as a first or primary function of the reference signature.

Thereafter, typically, an image digitizer, such as a standard vidicon digitizer, could be used to produce a digital image corresponding to the Fourier spectrum, displayed as an intensity function, of the reference signature. This digital image could, of course, properly be conceived to be a function of the first function.

Thereafter, this digital image might typically be superencrypted in accordance with one of the modes of superencryptment described hereinabove, producing a superencrypted image, which might be properly conceived of and spoken of as a function of said second function.

Further, in accordance with one of principles of the present invention, this third function might then be subjected to a superencryptment, such as a keyed superencryptment of the type described above, resulting in a digital image which might properly be conceived of as and spoken of as a function of said third funtion, i.e., the once superencrypted digital image.

This final, resulting, digital image, i.e., the cryptograph to be actually printed on a document of the particular signature verification system of the present invention, may be properly conceived of and spoken of as a compound function of the reference signature, which compound function is in fact compounded of said first, second, and third functions.

The term "digital image" as used herein is as broad as the definition of digital image of equation (2.3-1) found at page 23 of Gonzalez-Wintz.

Further, the term "digital image" as used herein also embraces coded arrays or coded images of the type shown in figures B.2, B.4, B.6, B.8, etc., of Gonzalez-Wintz.

An additional type of digital image embraced by that term as used herein is the type of coded array in which the various pixel values are displayed in bar-code form, rather than numerical or alphabetic form or grey level form.

Before considering the block diagrams of Figs. 3 and 4 in detail, it should be borne in mind that a typical signature verification system of the present invention will in general consist of:

1. At least one document imprinter for imprinting documents with reference signature cryptographs and sometimes with corresponding cryptokeys. A document imprinter may, of course, be a standard offset press of the type used in printing bank checks by the photo offset process, which makes use of reference signature cryptograph transparencies of the kind generated by a cryptograph transparency maker of the kind shown in schematic form in Fig. 3. As known to those having ordinary skill in the art, however, certain data-signal-operated, high-speed photo composing machines

are currently available which may be operated by signals like those produced by the reference signature transform encryptor of Fig. 3 to directly produce the reference signature cryptographs on the documents of a particular signature verification system at the same time that the rest of each document is being imprinted by the same data-signal-operated, high-speed photo composing machine.

2. A plurality of documents, such as bank checks, identity cards, or the like, each imprinted with a corresponding reference signature cryptograph, and in some cases a cryptokey, by the document imprinter or imprinters of the system.

3. Document readers for detecting counterfeit documents and exposing unauthorized presenters of genuine documents by comparing reference signature property data derived from the reference signature cryptographs of particular documents with data derived from the specimen signatures found on those respective documents. (A greatly advanced degree of security will be achieved, when the presenters of such documents are required to execute the specimen signatures in the presence of a human document receiver at the point of document presentation.)

For best understanding of the present disclosure, then, it should be borne in mind throughout that each individual signature verification system being discussed is made up of at least one document imprinter unique to the system, a plurality of documents unique to the system, and a plurality of document readers unique to the particular system.

The characteristic features of documents of the kind used in signature verification systems of the present invention, which documents themselves constitute a feature of the present invention, are discussed hereinabove in connection with Figs. 1A, 1B. 1C and 2.

A typical cryptograph transparency maker of the present invention is illustrated in block diagram form in Fig. 3, and will be discussed hereinbelow in connection therewith.

A particular document reader or document examining device typical of the document readers of document verifying systems of the present invention is shown in block diagram form in Fig. 4, and will be discussed hereinbelow in connection therewith.

Referring now to Fig. 3, there is shown a block diagram of a reference signature cryptograph transparency maker of the present invention.

As seen in Fig. 3, the cryptograph transparency maker 24 of that figure comprises an optical pickup unit 26 by means of which an image of the reference signature found on a particular reference signature card is picked up from the reference signature card and imaged onto the input planes of the two Fourier transformers of reference signature transformer 28.

Optical pickup unit 26 will be described in detail hereinbelow in connection with Figs. 22 and 23.

Reference signature transformer 28, which can be thought of as producing a first function of the reference signature on the reference signature card juxtaposed to optical pickup unit 26 will be described hereinbelow in connection with Fig. 24.

In brief, reference signature transformer 28 serves to convert the reference signature images provided by optical pickup unit 26 into electrical signals which represent a digital image of a logarithmic function of the Fourier

spectrum of the reference signature displayed as an intensity function.

Reference signature transform encryptor 30 will be described in detail hereinafter in connection with Fig. 25.

Reference signature transform encryptor 30 may be thought of as producing a cryptographic function of the function of the reference signature which is represented on the output connections of reference signature transformer 28. In other words, reference signature transform encryptor 30 may be thought of as generating a second compounded function of the reference signature, or as producing a function of the function of the reference signature produced by reference signature transformer 28.

In the terminology explained hereinabove, it may be said that reference signature transformer 28 and reference signature transform encryptor 30 together produce a compound or cascaded function of the reference signature, which compound or cascaded function is compounded of the function characteristic of reference signature transformer 28 and the function characteristic of reference signature transform encryptor 30, which functions may be called the "first function" and the "second function" in keeping with the terminology defined hereinabove.

As will be explained hereinbelow, reference signature transform encryptor 30 provides only a keyed superencryption of the function of the reference signature produced on the output connections of reference signature transformer 28, and does <u>not</u> impress upon the output signals of reference signature transformer 28 a universal superencryption, as that term is defined hereinabove.

It is to be understood, however, that the relative simplicity of reference signature transform encryptor of the described embodiment was adopted for simplicity and clearness of disclosure, and that a stage in reference signature transform encryptor 30 for applying a universal superencryptment to all of the cryptograph transparencies produced by cryptograph transparency maker 24 may be provided by one having ordinary skill in the art without himself exercising invention or engaging in undue experimentation, once such worker of ordinary skill is informed by the present disclosure.

Referring again to Fig. 3, it will be seen that cryptograph transparency maker 24 further comprises a cryptograph display unit 32. Cryptograph display unit 32 is further described hereinbelow in connection with Fig. 26. Essentially, cryptograph display unit 32 is a video monitor used for displaying the encrypted reference signature transform function carried by the output signals of reference signature transform encryptor 30. Although not shown in Fig. 3, it is to be understood that the deflection voltages which provide the raster scan of cryptograph display unit 32 conform to the special 64-line, one-field raster signals which are used throughout the cryptograph transparency maker, and the document reader of Fig. 4; the particular raster signals used in cryptograph display unit 32 being derived from the output raster signal generator of the reference signature transform encryptor of Fig. 25, as explained in detail hereinafter.

Transparency camera 34 of Fig. 3 is a transparency camera of well-known type, which is equipped with an electrically operated shutter and film advance. The electrically operated shutter and film advance of transparency camera 34 are operated by a suitable signal provided by cryptograph display unit 32 each time the generation of a reference signature cryptograph on its display screen is completed.

Referring now to Fig. 4, there is shown in block diagram form a document reader or document examining device of a preferred embodiment of the present invention.

As seen in Fig. 4, document reader 36 comprises two optical pickup units, viz., an optical pickup unit for a reference signature cryptograph of the kind described in detail hereinabove in connection with Fig. 1A and 1B, and an optical pickup unit for the corresponding specimen signature.

In what follows it will be assumed that, for the purpose of illustration only, the document being read by document reader 36 is bank check 10 of Fig. 1A.

It will further be assumed that means are provided for transporting check 10 past optical pickup units 38 and 40, and halting check 10 for a brief interval when reference signature cryptograph 16 is in registration with optical pickup unit 38, and corresponding specimen signature 12 is in registration with optical pickup unit 40. The assumed direction of check motion past optical pickup units 38 and 40 is indicated by arrow 42 in Fig. 1A.

Since the provision of such check transport means, including means for halting check 10 in registration with optical pickup units 38 and 40, is within the scope of those having ordinary skill in the art, such apparatus being regularly found in bank check processing centers, and the like, no details of the check transport mechanism employed will be given herein.

Similarly, only rudimentary details will be given of the means employed herein to produce a "belt halt" signal for initiating the operation of optical pickup units 38 and 40

when the belt carrying check 10 has come to a halt with reference signature cryptograph 16 and specimen signature 12 in registration with their corresponding optical pickup units, because the provision of apparatus for producing such a belt halt signal is well within the scope of one having ordinary skill in the art, such devices having been long well-known in many arts. Further, the selection of a high precision device of this kind operating on photoelectric vernier or Moire principles, where very high speed operation is desired, is well within the scope of those having ordinary skill in the art.

Similarly, the photo electric reader for the cryptokey bar code 18, 20 and check 10 is shown herein in rudimentary form only, it being well within the scope of those having ordinary skill in the art to provide more elaborate apparatus for this purpose, incorporating, e.g., self-checking features.

Optical pickup units 38 and 40 are described in detail hereinafter, in connection with Figs. 8 and 11, respectively.

Referring again to Fig. 4, it will be seen that check reader 36 comprises a cryptograph decoder 44. Cryptograph decoder 44 functions to strip from cryptograph 16 (Fig. 1A) the keyed superencryptment identified by cryptokey 18, 20 (Fig. 1A).

In other embodiments of the present invention the cryptograph decoder of the document reader will also serve to strip from the reference signature cryptograph on each particular document of the system a universal superencryptment, as that term is explained hereinabove.

For simplicity of illustration, however, the preferred embodiment described herein does <u>not</u> employ a universal superencryptment.

It should be noted here that cryptograph decoder 44 operates in a raster scanning mode. More particularly, the optical input system of cryptograph decoder 44 comprises a vidicon camera tube on the photocathode of which the reference signature cryptograph is imaged. The cathode ray beam of this vidicon camera tube is caused to sweep successively over each pixel of the photocathode image of reference signature cryptograph 16 (see dashed scanning lines 46, 48, 50 in Fig. 1B).

For this purpose, a 64-line, one-field raster is used throughout both cryptograph transparency maker 24 and document reader 36.

As noted above, reference signature cryptograph 16 is an array of 64 X 64 pixels of the insular type shown in Fig. 1B. Thus, the raster used in cryptograph transparency maker 24 and document reader 36, made up of 64 lines, in each of which 64 pixels is scanned, will hereinafter be called a 64 X 64 raster.

The provision of deflection voltage generating means for generating such a raster is well within the scope of those having ordinary skill in the art, and thus such means will not be described in detail herein.

As will now be evident to those having ordinary skill in the art, informed by the present disclosure, the vidicon tube of cryptograph decoder 44 produces a signal generally like the signal 52 of Fig. 1C, comprising a plurality of generally rectangular pulses or pedestals, such as pulses or pedestals 54, rising from a common level 56. It will also be evident that each pulse or pedestal corresponds to a particular pixel of reference signature cryptograph 16, and that the amplitude of each pulse or pedestal is determined by the grey level of its corresponding pixel (see Fig. 1B).

Referring again to cryptograph decoder 44, it should be noted that cryptograph decoder 44 further comprises a storage tube of well-known type and, means for writing on the storage electrode thereof, using the vidicon output signal and scanning raster, a representation of reference signature cryptograph 16.

Further, as described in detail hereinbelow, cryptograph decoder 44 also comprises scan control means whereby the storage electrode of said scan conversion storage tube is scanned in such manner as to produce an output signal from cryptograph decoder 44 which is representative of reference signature cryptograph 16 after being stripped of its superencryptment.

Referring again to Fig. 4, it will be seen that document reader 36 further comprises a specimen signature transformer 60.

As described in detail hereinbelow, specimen signature transformer 60 serves to optically and electronically produce from the optical image of specimen signature 12 picked up by optical pickup unit 40 a logarithmic function of the Fourier spectrum of specimen signature 12.

The expression "logarithmic function" is used because, as will be evident to those having ordinary skill in the art, the optical means generally used to generate Fourier spectra of patterns do not generate perfect spectra with perfect zero levels, and thus, since some background signal is always present when Fourier spectra of patterns are generated by actual optical equipment, it is not in practice necessary to add unity to the optically-generated Fourier spectrum elements in order to enhance the optical Fourier spectrum in the manner taught, e.g., at page 48 of Gonzalez-Wintz. See background 21' and Fig. 1B.

In specimen signature transformer 60 of check reader 36 of Fig. 4 an electrical representation of the thus enhanced Fourier spectrum of the specimen signature is stored in a scan conversion storage tube of the same type as the scan conversion storage tube used in cryptograph decoder 44.

Before considering comparator 62 of check reader 36, it should be noted that, in accordance with the principles of the present invention, the image stored in the storage tube of cryptograph decoder 44 is a basic compound function of the reference signature, and the image stored in the storage tube of specimen signature transformer 60 is the same basic compound function of the corresponding specimen signature on the same document.

More particularly, it should be noted that the apparatus of any particular embodiment of the present invention is so selected and constructed that, allowing for the imperfections of real physical apparatus, the images stored on the respective storage electrodes of the storage tubes of cryptograph decoder 44 and specimen signature transformer 60 would be substantially alike if the specimen signature on the document presented to the document reader for verification were replaced by a high quality photostat of the reference signature from which the corresponding reference cryptograph was made.

As will be evident to those having ordinary skill in the art, a certain degree of translation of the photostat of the reference signature will be tolerated by the apparatus of the invention, as will small translations of the actual specimen signature, because of the position-invariant properties of the Fourier transform, and the Fourier spectrum.

That is to say, it has been discovered in experimentally confirming the principles of the present invention that the Fourier transform and the Fourier spectrum are good handwriting style descriptors.

This handwriting-style-sensitive property of the Fourier spectrum may be demonstrated by generating a matrix of logarithmically enhanced Fourier spectra of "signatures" made in the following manner.

The names of N individuals are selected, and each of these N individuals writes his own name, i.e., executes his own signature, and also writes, in his own handwriting style, the respective names of the N-1 other participating individuals.

Thus, N^2 handwritten names are secured, of which only N are genuine signatures, the rest being the names of other individuals of the group of N, each written by another than the person whose name is written.

When logarithmically enhanced digital images of the Fourier spectra of all of these handwritten names, displayed as intensity functions, are closely juxtaposed and compared, especially in greatly reduced size, it becomes evident by simple, untrained observation that the Fourier spectrum images of names written by the same person, irrespective of what name he was writing, bear at least as good resemblance to each other, if not better, than the digital images corresponding to the same name written by different individuals.

Further, these same Fourier spectrum images can be cross-correlated by means of the algorithm of the present invention embodied in the formulas of Figs. 5, 6, and 7, and the above-said untrained visual observations will be confirmed.

This discovery that a function exists which is a handwriting style descriptor, and that the Fourier transform and Fourier spectrum are such functions, constitutes a part of the present invention. Referring again to Fig. 4, it will be seen that comparator 62 of check reader 36 serves to compare the output signals of cryptograph decoder 44 and specimen signature transformer 60.

The function of comparator 62 is to compare or cross-correlate the basic compound reference signature function signals produced by cryptograph decoder 44 and the basic compound specimen signature function signals produced simultaneously by specimen signature transformer 60.

Comparator 62 carries out the comparison algorithm of the present invention, as embodied in the formulae of Figs. 5 through 7, and thus constitutes in itself a part of the present invention.

Thus, as may be seen from examination of the formulae of Figs. 5 through 7, comparator 62 serves to produce an analog signal on its output terminal 64 each time a document is read or examined by document reader 36. This analog output signal on output terminal 64 of comparator 62 is proportional to the magnitude of the signature correlation coefficient C_s of the formula of Fig. 7.

Comparator 62 is described in detail hereinbelow in connection with Figs. 14 through 20.

Also shown schematically in Fig. 4 is the rejection indicator portion of check reader 36. In its simplest form, rejection indicator 66 comprises an operational amplifier which compares the C_s signal on line 64 with a threshold signal manually set by means of potentiometer in accordance with statistical experience with considerable numbers of test documents bearing reference signature cryptographs and corresponding specimen signatures.

As will be appreciated by those having ordinary skill in the art, it is not to be expected that statistical experience will result in a "perfect" threshold level voltage, which can be set and the threshold potentiometer thereafter left unchanged.

Rather, it is to be expected that, particularly in the banking industry, the threshold settings of devices embodying the present invention must be left to be chosen by the users, e.g., the experienced bank officials in charge of large check processing centers, for the reason that a different threshold setting may be desired by particular officials when dealing with relatively low face value checks, as compared with the setting when dealing with high face value checks.

It is also contemplated that in some embodiments of the present invention simple "adaptive" or "learning" devices will be employed to determine the threshold level in the rejection indicator in accordance with prior experience with the percentage of checks rejected.

Rejection indicator 66 will be discussed hereinbelow in further detail in connection with Fig. 21.

Referring again to Fig. 4, it will be seen that check reader 36, in the overall system sense, also comprises a document rejector 68.

Many document rejector concepts and systems are well-known to those having ordinary skill in the art.

For instance, some systems directly reject spurious documents, while others stamp or otherwise mark the spurious documents, e.g., in fluorescent ink, whereafter the spurious documents

are photoelectrically selected and removed from the flow of documents through the apparatus.

Since the paper handling art is well developed, including the art of document rejection means, and thus the provision of both paper handling and paper rejecting apparatus is well within the scope of one having ordinary skill in the art, such means will not be described in detail herein.

Before describing in detail the preferred embodiment of the apparatus of the present invention shown in Figs. 8 through 26, the convention adopted herein for indicating circuit interconnections between different figures of the drawings will now be described.

Both the circuit of the document reader of the preferred embodiment and the circuit of the cryptograph transparency maker of the preferred embodiment are divided into a pluarlity of different figures.

Each link (i.e., interconnection having negligible impedance) extending between circuit points located in different figures of the drawings is specified herein by means of the following conventions:

1. From each of such circuit points there extends a lead which terminates adjacent an edge of the figure in point lies.

Example: The lead extending from the rectangle with the legend RC to the right-hand edge of Fig. 8.

2. Each figure is assumed to have four of such edges which together form a rectangle which is the locus of the ends of all such leads.

3. One of said four edges is arbitrarily designated

the top (or T) edge, and the other three edges are then designated the right-hand (or R), bottom (or B), and left-hand (or L) edges, in clockwise order.

4. Any lead which terminates adjacent an edge of a figure is considered to be, and is called, a terminal of that figure.

5. Each terminal of a figure of the drawings is uniquely identified by a code designation, called a "home number", which may be easily deduced from the figure itself if not located immediately above the terminal.

6. Each home number consists of three terms: the first term, the middle (or alphabetic) term, and the third term.

7. The right-hand letter of the alphabetic term of every home number (or the single letter if there is only one letter) at the T-edge of every figure is T. The right-hand letter (or single letter if there is only one letter) of every home number at the R-edge of every figure is R. The right-hand letter of the alphabetic term (or single letter if there is only one letter in the alphabetic term) of the home numbers at the B and L edges are B and L, respectively. When the alphabetic term consists of more than one letter, all the letters of the alphabetic term but the right-hand letter are part of the figure designation.

Example: The home number 10AL1 will be located immediately above the uppermost lead extending to the left-hand edge of Fig. 10A.

8. Every home number in each figure has as its first term the number of that figure. When the alphabetic term is made up of more than one letter, all of the letters except the rightmost letter are part of the figure number. It should be noted that the practice may sometimes be observed of enclosing the literal part

of the figure number in parentheses, to avoid confusion.

9. The third terms of the home numbers at any subfigure edge are identifying numerals assigned to the terminals at that edge. All along the R and L edges these identifying numerals generally increase in order from the T-edge toward the B-edge. Similarly, the identifying numerals (third terms) of the home numbers along the T and B edges increase in order from the L-edge toward the R-edge.

10. The home numbers of one or more other terminals will be found near certain terminals in the figures of the drawings. These remote terminal home numbers are called "remote numbers" and serve to indicate the remote terminals to which the adjacent terminal is linked, i.e., interconnected by an interconnection having negligible impedance. By "adjacent terminal" in the previous sentence is meant the terminal adjacent which the remote number is set.

The expression "terminal number" is used when a term generic to both home numbers and remote numbers is required. Specifying more than one link to interconnect any pair of points <u>does not</u> imply that more than one such link is to be used in constructing an embodiment of the invention; the redundant links are specified merely for convenience in circuit tracing and <u>not</u> to indicate necessary structure.

The document reader 36 of Fig. 4 will now be described in detail, with reference to the detail figures of the drawings referred to beneath the various subcombination blocks of Fig. 4.

Referring now to Fig. 8, there is shown schematically a check transport belt 70, which carries a plurality of check carriers 72, 74, 76, etc.

As pointed out hereinabove, the provision of suitable check handling means is well within the scope of those having ordinary skill in the art, and thus belt 70, and the means for advancing belt 70 and halting the same at the required times, is not shown or described in detail herein.

It will be assumed for present purposes, however, that belt 70 is a Geneva-driven belt, which halts or pauses when each check carrier is properly juxtaposed to optical pickup units 38 and 40 so that the reference signature cryptograph is imaged on the photocathode of the vidicon of decoder 44 (Fig. 4), and the specimen signature is imaged on the photocathodes of the two vidicons of specimen signature transformer 60, as explained hereinbelow.

Further, it is assumed that before each check carrier has thus halted other photoelectric apparatus (described hereinbelow) has read cryptokey 18, 20 of check 10 (Fig. 1A).

Also shown in Fig. 8, is the optical system 78 by which the reference signature cryptograph on the document being read or examined is imaged onto a beam splitter 80.

A light source 82 of well-known type directs its illuminating rays toward the "half-silvered" plane 84 of beam splitter 80, and these rays thus illuminate the reference signature cryptograph of the check in check carrier 74 (momentarily halted).

A reflected light image of cryptograph 16 (check 10 being assumed to be in carrier 74) is projected by optical system 78 through "half-silvered" plane 84 and upward through the top surface of beam splitter 80 (arrow 86).

As may be seen from the termination of arrow 86 in Fig. 9, the image of reference signature cryptograph 16 is projected upon the photocathode of the decoder vidicon 112 (Fig. 9).

Also shown in Fig. 8 is the belt halt signal generator, generally indicated by the reference numeral 90.

It is assume that a portion of the upper surface of belt 70 is marked with a series of closely-spaced, narrow transverse markings 92. Markings 92 are perpendicular to the longitudin dimension of belt 70, and this array of closely spaced, transverse markings extends continuously around the entire length of belt 70, i.e., if belt 70 were cut the array of markings 92 would extend continuously from end to end thereof.

A light source 94 and associated photosensor 96 are provided, whereby the amount of light impingent on the photosensitive element of photosensor 96 varies cyclically as marks 92 pass through the spot of light projected by optical system 94.

Thus photosensor 96 provides a train of electrical impulses when, and only when, belt 70 is moving.

The input terminal of a monostable multi-vibrator 98 is connected to the output or signal terminal of photosensor 96 by a lead 100.

Thus, in the well-known manner, monostable multivibrator 98 remains in its set state as long as belt 70 is moving, because its period is sufficiently long so that setting pulses are supplied by photosensor 96 via line 100 before monostable multi-vibrator 98 can reset itself.

However, almost immediately after belt 70 has come to a halt, and the setting pulses from photosensor 96 are no longer supplied, monostable multi-vibrator 98 resets itself, bringing about a transition or step signal on line 102.

In the well-known manner, RC network 104 acts upon the transition or step signal on line 102 to provide a corresponding pulse on line 106.

Thus, it will be seen that belt halt signal network 90 serves to produce a pulse on lead 106 whenever belt 70 comes to a halt.

The oppositely-directed pulse produced when belt 70 recommences its motion is, of course, suppressed in the well-known manner.

Referring now to Fig. 9, it will be understood from the presence of remote number 8R1 at terminal 9L1 that the belt halt signal produced on line 106 of Fig. 8 is directly applied to an input terminal of decoder vidicon beam deflection voltage generator 110.

As pointed out above, cryptograph 16 is already imaged on the photocathode of decoder vidicon 112.

Deflection voltage generator 110 produces suitable voltages on leads 114 and 116 to cause the scanning beam of vidicon 112 to scan its photocathode, producing a corresponding output signal on lead 118.

Deflection voltage generator 110 produces the type of raster scan referred to hereinabove as a 64X64 raster scan, and thus the scanning beam of vidicon 112 scans its photocathode in such a manner as to pass through the portions thereof

corresponding to the successive pixels of cryptograph 16 (see Fig. 1B), producing a signal of the general type illustrated in Fig. 1C on lead 118.

As seen in Fig. 9, the signal on line 118 is applied to decoder storage tube 120.

Although many image storage tubes may be employed in carrying out the present invention, the tube employed in the preferred embodiment is of the type known as a Radechon, which has the advantage of not requiring erasing, since the writing of a new signal automatically erases the previous signal, and also the advantage of recording an image signal in a single scan. See Storage Tubes and Their Basic Principles, by M. Knoll and B. Kazan, John Wylie and Sons, Inc., New York, 1952, pages 61 through 65.

Suitable amplifiers and matching networks, etc., as may be required between the output terminal of vidicon 112 and the backplate input connection of Radechon 120, will be supplied by those having ordinary skill in the art without the exercise of invention, and thus are not indicated herein. Thus, it will be assumed herein that interconnection 118 includes such amplifiers, matching networks, etc., as will be supplied by ordinary skill.

As shown in the above-cited Knoll and Kazan text on storage tubes (hereinafter "Knoll and Kazan"), the Radechon tube has but one scanning beam. In the device of the preferred embodiment herein, as in other applications of the Radechon storage tube, this single scanning beam is scanned by one raster generator or deflection voltage generator during writing, and is scanned by a different deflection voltage generating arrangement during reading, as described in detail hereinafter.

As seen in Fig. 9, a deflection voltage generator 124 provides scanning voltages for bringing about the scanning of the single scanning beam of Radechon 120 during the writing of the reference signature cryptograph information on line 118 onto the image storage electrode of Radechon 120.

A high frequency wall voltage generator 126, of well-known kind, it provided to superpose a low amplitude, high frequency wobble voltage on the vertical deflection voltage produced by deflection voltage generator 124, so that the representation of each pixel on the image storage electrode of Radechon 120 will have considerable width transverse to the sweep direction, as do the pixels of Fig. 1B, thereby reducing registration problems.

In keeping with the nature of the Radechon tube, both deflection voltage generator 110 and deflection voltage generator 124 are so constructed and arranged as to scan out only one complete raster each time they are triggered.

Deflection voltage generator 110 is triggered by the belt halt signal, as described above, and deflection voltage generator 110 provides a simultaneous trigger signal to deflection voltage generator 124 via lead 128. Thus, the photocathode of vidicon 112 and the image storage electrode of Radechon 120 are simultaneously scanned in synchronism, and thus the image of reference signature cryptograph 16 on the photocathode of vidicon 112 is written on the image storage electrode of Radechon 120.

A suitable inhibiting gate 130 is provided in the output lead of Radechon 120 to block the well-known difference signal which exists on the output lead when a new image is being written on the image storage electrode thereof. A blocking signal for operating gate 130 is supplied by de-

flection voltage generator 124 via lead 132 whenever deflection voltage generator 124 is producing a scanning raster.

Deflection voltage generator 110 produces a signal on lead 134 whenever it is not producing raster scanning voltages.

Since deflection voltage generators 110 and 124 operate in synchronism, it will be seen that the signal on lead 134 indicates that the writing of the cryptograph image into storage tube 120 has terminated.

A similar signal, indicating that the logarithmic function of the Fourier spectrum of specimen signature 12 has been written into the storage tube of specimen signature transformer 60 is provided on lead 136 (link 9T1-12T1).

Thus, gate 138 produces a step or transition signal on its output lead 140 when both the storage tube in cryptograph decoder 44 and the storage tube in specimen signature transformer 60 have been "loaded".

The step or transition signal on lead 140 triggers monostable multivibrator 142, and after a suitable brief delay the return of monostable multivibrator 142 to its reset state produces a transition signal on lead 144 which causes RC network 146 to produce a pulse on line 148 suitable for triggering deflection signal generators 150 and 152 into simultaneous action.

The storage tube reading beam deflection generators 150 and 152 provide the basic raster scanning signals for reading information from the information storage electrodes of the information storage tubes of cryptograph decoder 44 (Fig. 9) and specimen signature transformer 60 (Fig. 12).

As seen in Fig. 9, the horizontal deflection signal from signal generator 152 is amplified by a suitable amplifier 154 and then applied to the horizontal reading beam deflection electrodes of radicon storage tube 120. A suitable network may, of course, be provided by those having ordinary skill in the art to permit the alternative application of writing and reading raster signals to the deflection electrodes of radicon storage tube 120, such networks having been long known in particular applications of the radicon storage tube.

A similar network will be provided in connection with the storage tube of specimen signature transformer 60 (Fig. 12).

Reading beam deflection generators 150 and 152 also provide the readout scanning raster voltages for the storage tube of specimen signature transformer 60 (Fig. 12), via links 9B4-12R3 and 9B5-12R4, and amplifiers 156 and 158 (Fig. 12).

As will be seen in Fig. 9, the veritical deflection signal supplied by storage tube reading beam deflection signal generator 150 is not applied directly to the vertical reading beam deflection voltage terminal 160 of storage tube 120.

Rather, the output signal of storage tube reading beam deflection signal generator 150 on line 162 is applied to the input terminals 164, 166, 168, of three decoding deflection signal generators 170, 172, 174.

Each of the decoding signal generators 170, 172, 174 provides a unique deflection signal output, whereby the reading time of certain pairs of rows of pixels stored on the information storage screen of radicon tube 120 are interchanged.

A schematic representation of a simple case of such an interchange is shown schematically by the curve 176 of Fig. 27. Taking curve 176 to represent a small portion of the vertical deflection voltage of a scanning raster, the horizontal deflection voltage being the usual, unmodified step voltage, it will be seen that when row signals A, B, C, D, E, F, G, and H are presented in that order during the scanning of this special modified raster, the times of occurrence of rows F and D are interchanged. It will also be evident from Fig. 27 that when the row signals A through H are presented in this modified order (lower horizontal row of capital letters, Fig. 27) during scanning by the same modified scanning raster, the original alphabetic order of occurrence of the respective row signals will be restored (right-hand column of letters A through H, Fig. 27).

The mode of superencrypting reference signature cryptographs, and the mode of stripping these superencryptions from reference signature cryptographs, in the present preferred embodiment are both based upon the principle illustrated in Fig. 27.

Returning to Fig. 12, and bearing in mind said principle, it will now be seen by those having ordinary skill in the art, informed by the present disclosure, that each of the deflection signal generators 170, 172 and 174 produces a different modified vertical deflection signal, whereby different pluralities of pairs of scanning rows are mutually interchanged in the manner taught in connection with Fig. 27.

Many means of thus modifying vertical raster deflection signals will occur to those having ordinary skill in the art without the exercise of invention. One such device is the beam deflection tube of United States Patent No. 2,643,289, issued to George C. Sziklai on June 23, 1953, and particularly

the photoelectric version thereof. By directly interconnecting targets 53 and 54 of this Sziklai tube, and by providing apertures in mask 60 each having a total width equal to the desired momentary "step amplitude" of the desired modified vertical scanning signal, and desired modified vertical scanning signal can be easily provided. In this case, of course, the basic vertical scanning signal (line 162, Fig. 9) will be applied, through a suitable amplifier, to the upper vertical deflection plate 52 of the Sziklai tube, while the potential on the control grid 48 of the Sziklai tube is maintained constant.

It will also be evident to those having ordinary skill in the art that the equivalent photoelectric tube described in the above-cited Sziklai patent, employing wedges or masks external to the tube, may be preferable for reasons of flexibility and economy, since each vertical scan modification tube used would then be identical to every other vertical scan modification tube, the only variation being in the associated external masks or wedges, and the external masks or wedges could be made interchangeable to permit a change in reference signature cryptograph encryptment codes.

Other electronic arbitrary function generators may be used for the same purpose, e.g., the electronic arbitrary function generator of United States Patent No. 3,037,123, and the function generator of United States Patent No. 2,907,888.

In view of the above, it will be understood that each of the deflection signal generators 170, 172 and 174 (Fig. 9) may be a tube of the Sziklai type, as just described, along with a suitable amplifier, and that thus each of the deflection signal generators 170, 172, and 174 is capable of providing on its respective output lead a unique modified vertical deflection signal, the vertical deflection signals on leads

178, 189 and 182 each differing from both of the others in a predetermined manner.

It will now be also understood that each of the modified vertical deflection signals appearing at leads 178, 180, and 182, when applied through a suitable amplifier to vertical deflection input terminal 160 of radicon storage tube 120, in synchronism with the corresponding horizontal deflection signal supplied by amplifier 154, is capable of mutually interchanging several pairs of rows of pixels as read from the information storage electrode of storage tube 120, as explained hereinabove in connection with Fig. 27.

As also seen in Fig. 9, a vertical reading beam deflection signal amplifier 184 is connected to provide deflection signals to vertical deflection signal terminal 160, and to derive its input signal from any one of three gates 186, 188, 190.

Further, it will be seen that each of these gates is controlled by a corresponding signal, supplied by links 9B1-10BL3, 9B2-10BR1, and 9B3-10BR2, respectively.

As explained hereinbelow in connection with Fig. 10B, only one of these gate-opening signals is provided at a time, the particular gate-opening signal provided at any time being selected in accordance with the cryptokey imprinted on the document being examined.

Thus, it will be seen that in the device of the preferred embodiment the times of occurrence of certain pairs of line scans or row scans of the cryptograph decoder storage tube 120 are interchanged, the number and identity of these interchanges being determined by the cryptokey imprinted on the document being examined.

An additional property of the scanning rasters provided by deflection signal generators 150 and 152, which can be provided by one having ordinary skill in the art without the exercise of invention, is the fact that each horizontal line or row is scanned twice in succession. The reason for the adoption of this double scan will be evident from the formulae of Figs. 5 through 7, from which it will be seen that the data of each horizontal row of pixels stored in the abovesaid storage tubes must be scanned twice, once for the generation of U_x, and once for the generation of C_x.

Additionally, for delineation of the two successive stages of operation of comparator 62, in computing U_x and then computing C_x, line scan time marker generators 194 and 196 are provided (Fig. 9). The first line scan time marker generator 194 provides a signal which continues to exist during the first scanning of each line of the raster generated by deflection generators 150 and 152.

The second line scan time marker generator 196 produces a continuous signal during the second scanning of each horizontal line of raster generated by deflection signal generators 150 and 152.

Additionally, a pixel time marker signal generator 198 is provided, which provides a marker pulse near the beginning of each pixel time, i.e., just after the commencement of the sweeping of each pixel stored on the information storage electrode of storage tube 120 by the reading beam thereof.

As also seen in Fig. 9, a subcircuit comprising a gate 200, an RC network 202, and a delay circuit 204 is provided for producing at terminal 9R6 a signal indicating that the reading of storage tube 120 and the corresponding storage tube of specimen signature transformer 60 has been completed,

and a sufficient delay ensued so that the storage tubes may be erased, etc., in preparation for a new cycle of storage tube operation.

As seen at the top center of Fig. 9, terminal 9R6 is directly linked to terminal 9T2, which is the erasing signal terminal of storage tube 120 and its associated supply network. Upon receipt of each 9R6 signal, the electrode potentials of storage tube 120, etc., are so switched that the information storage electrode of storage tube 120 is erased, and then storage tube 120 is returned to its writing mode, ready to receive the reference signature cryptograph information from the next document examined.

Going now to Fig. 10A, there is shown the cryptokey reader 210, adapted for reading cryptokeys from checks being examined, e.g., the cryptokey 18, 20 of bank check 10 of Fig. 1A.

As pointed out hereinabove, cryptokey reader 210 is so positioned with respect to optical system 78 of Fig. 8 as to read the cryptokey from a document being examined, e.g., 18, 20 of check 10 of Fig. 1A, before the cryptograph and specimen signature come into registration with optical pickup units 38 and 40 (Fig. 4).

Cryptokey reader 210 comprises two identical illuminating systems 212, 214 (only one shown), and two photocell pickup systems 216, 218 (only one shown).

Photocell pickup system 216 comprises a photosensor 220, and photocell pickup system 218 comprises a photocell 222.

As, e.g., check 10 is moved into reading registration with optical pickup units 38 and 40, the light beam from source 214 traverses cryptograph key clock track 18, and the light

beam from source 212 traverses cryptograph key information track 20 (Fig. 1A).

Thus, the light falling on the respective photosensors 220 and 222 is modulated in accordance with the cryptograph key information of track 20 and the cryptograph key clock information of track 18.

The resulting key clock and key information signals are impressed upon photosensor leads 10AL1 and 10AL2, respectively.

Going now to Fig. 10B, it will be seen that the key clock and key information signals from links 10AL1-10BL1 and 10AL2-10BL2 are impressed upon an EXCLUSIVE OR gate 224.

By this means only clock pulses <u>not</u> paired with an information pulse pass through EXCLUSIVE OR gate 224 to the count input of key counter 226.

In the well-known manner, the configuration of signals on parallel output leads 228-238 of key counter 226 change in response to the receipt of successive input pulses on the count input.

As was explained hereinabove in connection with Fig. 9, only three possible superencryptments, corresponding to generators 170, 172 and 174 are provided in the device of the preferred embodiment.

Correspondingly, each check to be read by the device of the preferred embodiment is imprinted with one of three unique cryptokeys, to which there corresponds a unique number of pulses emitted by gate 224.

It follows, then, that for each of the three cryptokeys of the system of the preferred embodiment there is a unique configuration of signals on parallel output leads 228-238 of key counter 226.

Three interpreting gates 240, 242, and 244 are provided, each of which, in the well-known manner, produces a unique signal on its output lead when, and only when, key counter 226 has been pulsed to contain a corresponding count, which in turn corresponds to one of three cryptokeys imprinted on the checks of the system of the preferred embodiment.

Thus, it can be seen that whenever a cryptokey is read from a document being examined one of the three gates 240, 242, 244 provides a unique output signal.

Since the output terminal of each of these gates is connected to a corresponding gate 186, 188, 190 of Fig. 9, it follows that the reading of one of the three cryptokeys of the system by cryptokey reader 210 results in the selection of one particular modified vertical sweep signal for application to the reading beam deflection electrodes of decoder storage tube 120 when belt 70 has halted and the cryptograph and specimen signature on the same document are in registration with optical pickup units 38 and 40.

As will also be seen in Fig. 10B, the abovedescribed signal on terminal 9R6 is linked to key counter 226 via link 9R6-10BT1, and thereby key counter 226 is cleared shortly after the storage tubes of cryptograph decoder 44 and specimen signature transformer 60 have been read out.

Referring now to Fig. 10A there is shown the optical pickup unit 40 for imaging the specimen signature on a check or other document being examined onto the photocathodes of the input vidicons of specimen signature transformer 60.

It is assumed in Fig. 11 that belt 70 has halted in such a position that the specimen signature on check 10 in check carrier 74 is in registration with optical pickup unit 40.

Optical pickup unit 40 comprises two light soucres 250, 252.

The production of suitable uniform light sources is discussed in Appendix III of Noncoherent Optical Processing, by G.L. Rogers, John Wiley and Sons, New York, 1977, and will not be discussed here. This text will hereinafter be referred to as "Rogers".

Specimen signature 12 is imaged by a lens system 254 into a two-way beam splitter 256 of a well-known type.

Two-way beam splitter 256 directs images of specimen signature 12 into two one-way beam splitters 258, 260.

Two light beams 262, 264 emerge, respectively, from one-way beam splitters 258, 260, light beams 262, 264, carrying substantially identical images of specimen signature 12 to specimen signature transformer 60 (Fig. 12). Before discussing in detail specimen signature transformer 60 in connection with Fig. 12, it should be noted that light sources 250, 252 of Fig. 11 are noncoherent light sources.

The optical pickup unit for specimen signatures 40 and the specimen signature transformer 60 of the system of the preferred embodiment are designed to produce a logarithmic function of the Fourier spectrum of the specimen signature by the use of coherent light because the system of the preferred embodiment is designed for use in connection with bank checks, many of which are printed on a fairly low grade of unfilled paper, often provided with a "scenic" overprint.

Given the matte surfaces of such papers, altered in not fully determined ways of being thus overprinted, it cannot be determined without an exhaustive survey, which has not yet been undertaken, whether sufficiently good reflective images of specimen signatures can be produced from all such bank check surfaces by reflected coherent light.

It is for this reason that optical pickup unit for specimen signatures 40 and specimen signature transformer 60 are disclosed herein as noncoherent light devices.

It will, of course, be obvious to those having ordinary skill in the art that if possible the use of coherent light devices is to be preferred, since thereby the amount of equipment used is greatly reduced, and the cost of the equipment of systems of the present invention, along with their complexity, greatly reduced.

For example, in a coherent light system embodying the present invention the beam splitters 256, 258, 260 would be eliminated, the sine transformer and cosine transformer of Fig. 12 would be replaced by a simple biconvex lens (see Introduction to Fourier Optics, by J.W. Goodman, McGraw-Hill, 1968, pages 83 through 90), one vidicon tube would be eliminated from the specimen signature transformer 60 of Fig. 12, and the two squarers, the summer, and the half-log function generator eliminated as well.

It is presently anticipated that coherent light may be usable in systems embodying the present invention, although resort may have to be had to some of the methods discussed in "Effects of Coherence on Imaging Systems", Journal of the Optical Society of America, Volume 56, No. 8, August, 1966 by Philip S. Considine. It is to be understood that all systems embodying the present invention, whether

employing coherent or noncoherent light, fall within the embrace of the present invention.

Referring now to Fig. 12, it will be seen that specimen signature transformer 60 comprises a "cosine transformer", or more particularly, a noncoherent light Fourier optical cosine transformer 268, and a "sine transformer" or noncoherent light Fourier optical sine transformer 270.

Such Fourier optical sine and cosine transformers for use with coherent light are well-known to those having ordinary skill in the art. See United States Patent No. 3,669,528, issued to John M. Richardson on June 13, 1972, and, inter alia Chapter 5 of Rogers, and the sources there cited.

Other means than the means of Fig. 11 for providing input image signals to Fourier transformers 268 and 270 will be provided by those having ordinary skill in the art without the exercise of invention.

For example, in some systems it may be found desirable to eliminate lens system 254 (Fig. 11), and to pass the diffuse reflected light from specimen signature 12 (Fig. 11) directly to Fourier optical transformers 268 and 270 through beam splitters similar to beam splitters 256, 258, and 260, but of much wider angle.

Alternatively, it may be desirable to halt belt 70 twice, thus making it possible to directly expose the input ends of the Fourier transformers 260, 270 to specimen signature 12, employing the well-known storage property of vidicon to maintain the image derived from one transformer until the image derived from the other transformer is picked up, when belt 70 halts for the second time.

As further seen in Fig. 12, a beam splitter 272 is closely juxtaposed to the output end of cosine transformer 268, and a beam splitter 274 is closely juxtaposed to the output end of sine transformer 270.

Closely juxtaposed to the output surface of beam splitter 272 is an optical element 276 which will herein be called a "pixel averager", and will be described hereinbelow in connection with Figs. 13A through 13C.

As further seen in Fig. 12 a vidicon tube 280 is located closely adjacent pixel averager 276, and a vidicon tube 282 is positioned closely adjacent pixel averager 278.

A lens 284 is provided for imaging the near face of pixel averager 276 onto the photocathode of vidicon 280, and a lens 286 is provided for imaging the near face of pixel averager 278 onto the photocathode of vidicon 282.

Going now to Figs. 13A through 13C, it will be seen that the pixel averager of the present embodiment, to which pixel averagers 276 and 278 are identical, consists of a glass face plate 290, a second glass face plate 292, and a perforated structure 294 disposed therebetween F18.

As may be seen by comparison of Figs. 13A and 13B, the perforations 296 in body 294 are generally tapered, narrowing from their open ends at plate 290 to their open ends at plate 292.

As also seen by comparison of Figs. 13A and 13B, the peripheries of the ends of perforations 296 adjacent plate 290 are substantially coincident, while the peripheries of the open ends of perforations 296 adjacent plate 292 are much smaller.

Thus, as may best be seen in Fig. 13B, the common sides of the peripheries of adjacent perforation openings 298 are substantially coincident, and, by contrast, the peripheries 300 of the lower, smaller ends of the adjacent perforations 296 are considerably remote from each other, the area of the lower opening surrounded by periphery 300 being less than one-third the area of the larger, upper opening bounded by periphery 298.

Plate 290 is provided with a frosted or diffusing surface on its inner face 302, and plate 292 is provided with a frosted or diffusing surface on its inner face 304. As will now be evident to those having ordinary skill in the art, the pixel averagers of the device of the present embodiment serve to subdivide a light image impingent on diffusing face 302 into a plurality of pixels, and to concentrate the light of each such pixel, at the same time substantially averaging it, so that the light emitted by the area of diffuse surface 304 at each lower aperture 300 is substantially proportional to the average of the image illumination falling upon the corresponding pixel, or upper aperture 302.

Thus, returning to Fig. 12, it will be seen that the combination of pixel averager 276 and lens 284 serve to impinge upon the photocathode of vidicon 280 a pattern of isolated light islands (herein called "pixels"), the intensity of which is substantially equal to the average light falling upon the corresponding large pixel area 302 (Fig. 13A) of pixel averager 276.

The image falling upon the photocathode of vidicon 280 when a specimen signature is in registration with optical pickup unit 40, then, will generally resemble Fig. 1B, except for the dashed scan lines 48, which are theoretical only and do not appear on the actual vidicon photocathode.

The intensity or grey level of each pixel imaged on the photocathode of vidicon 280 will, of course, be determined by the output image of Fourier cosine transformer 268, which in turn depends upon the configuration of the specimen signature presented to optical pickup unit 40.

Pixel averager 278 and lens 286 similarly function with beam splitter 274, Fourier sine transformer, etc., to image upon the photocathode of vidicon 282 a digital image of the output image of Fourier sine transformer 270, a local area of this digital image impingent on the photocathode of vidicon 282 generally resembling Fig. 1B, with the exceptions above noted.

As is well-known to those having ordinary skill in the art, the complete Fourier transform, or in this case, Fourier spectrum, or rather the digital image thereof, can be produced by taking the square root or the sum of the squares of the intensities or grey levels of the corresponding pixels of the output images of the sine transformer and cosine transformer, respectively, and storing or displaying the resulting array of pixel intensities or grey levels, in the same juxtaposition as the corresponding pixels of the digitized output images of the sine and cosine transformers.

As will be evident to those having ordinary skill in the art in view of the following discussion, this function is carried out by the circuit shown in the central portion of Fig. 12, and the resulting logarithmic function of the Fourier spectrum of specimen signature 12 is stored on the information storage electrode of the transformer storage tube of Fig. 12.

The vidicon beam deflection voltage generator 310 of Fig. 12 is generally similar to vidicon beam deflection voltage generator 110 of Fig. 9, and like vidicon beam deflection

voltage generator 110 of Fig. 9 generates raster scanning voltages conforming to the above-described 64 X 64 raster when suitably triggered. Vidicon beam deflection voltage generator 310 is triggered by the belt halt signal which also triggers vidicon beam voltage generator 110, received over link 8R1-12L1.

As seen in Fig. 12, vidicon beam deflection voltage generator 310 provides 64 X 64 raster scan voltages to both vidicon 280 and vidicon 282.

Vidicon beam deflection voltage generator 310 is provided with an output terminal 312 whereat is produced a triggering signal coincident with the triggering signal on terminal 12L1 which initiates the operation, through a single raster cycle, of vidicon beam deflection voltage generator 310.

As seen in Fig. 12, terminal 312 is connected directly to a delay circuit 314, which may be any of many well-known types. Delay circuit 314 produces a delay of very short duration, to compensate for the finite time involved in computing the square root of the sum of the squares of the corresponding pixel values derived from the photocathodes of the two vidicons 280 and 282. The output of delay circuit 314 is a triggering impulse which is applied to storage tube writing deflection voltage generator 316, and which inititates the raster cycle of storage tube writing deflection voltage generator 316.

Storage tube writing deflection voltage generator 316 is provided with a wobble generator which is substantially identical to the wobble generator 126 of Fig. 9, and is provided for the same purpose.

The output signals of vidicon 280 and 282, on lines 320 and 322, respectively, are applied directly to squarers 324 and 326, respectively.

Squarers 324 and 326 are high speed squaring devices, such as OK-256 or OK-329 beam deflection squaring tubes (See Electronics, February, 1955, pages 160 through 163, and Electronics, August, 1950, pages 122, 174, 175, and 176.) Alternatively, it may be desired to employ an electronic arbitrary function generator, such as the function generators of the above-cited United States Patents 2,907,888, and 3,037,123.

As is well-known to those having ordinary skill in the art, these devices are all free-running analog devices, which produce on an output lead a voltage proportional to the analog voltage on an input lead, some at extremely high speeds.

Thus, it will be seen that squarer 324 produces on its output lead 328, when vidicon 280 is scanning any pixel image on its photocathode, an analog voltage proportional to the square of the intensity or grey level of that pixel image.

Similarly, squarer 326 produces on its output lead 330, when the sweep beam of vidicon 282 is transiting the corresponding pixel, an analog voltage which is proportional to the square of the intensity or grey level of that pixel.

Since the corresponding pixels in vidicons 280 and 282 are scanned substantially simultaneously, summer 332 will simultaneously receive, on lines 328 and 330, the abovesaid two analog square signals.

Analog summing means suitable for use as summer 332 will be provided by those having ordinary skill in the art without the exercise of invention. In addition, the high output impedance of squarers 324 and 326, particularly if the above-suggested beam deflection tubes are used, will make it possible to use a very simple analog summer for summer 332. Alternatively, a more elaborate summer, such as a computing tube summing arrangement of the kind disclosed in United States Patent No. 2,993,645, issued to W.J. Spaven on July 25, 1961, may be desirably employed.

For each corresponding pair of pixels on the photocathodes of vidicons 280 and 282, being simultaneously scanned, then, the analog output voltage on output terminal 334 of summer 332 will be proportional to the sum of the squares of the intensities or grey levels of those two pixels.

Half-log function generator 336 may, for example, be an electronic arbitrary function generator, such as those of the above-cited United States Patents 2,907,888, and 3,037,123, or may be a beam deflection tube of the type of the above-cited Sziklai patent, and more particularly may be one of the photo-electric-beam deflection tubes of the above-cited Sziklai patent, in which the optical wedges are graduated in accordance with the half-log function. F38

All of these devices, like squarers 324 and 326, and summer 332, are free-running analog devices, and thus the signal produced at output terminal 338 of half-log generator 336 whenever a corresponding pair of photocathode pixel images are being scanned in vidicons 280 and 282 will be a logarithmic function of the square root of the sum of the squares of the intensities or grey levels of those two corresponding pixels.

As pointed out hereinabove, the term "logarithmic function" of the Fourier spectrum of the specimen signature is used herein because the intensity or grey level values of pixels derived from the vidicons 280 and 282 will necessarily be referred to an artificial non-zero level, rather than an absolute zero level, because of the nature of the blank checks upon which the specimen signatures are written. Further, these other-than-zero levels may vary from check to check, especially when going from a non-scenic check to a "scenic" check.

Thus, the magnitudes of the successive signals at output terminal 338 of half-log function generator 336 will not necessarily be direct logarithmic functions of the corresponding pixel Fourier spectrum values, but rather will be logarithmic functions of the sum of some quantity plus the square root of the sum of the squares of the two vidicon photocathode pixel values. As pointed out immediately above, this "quantity" will probably vary somewhat from check to check.

It cannot be determined at this time whether, for optimum use of the system of the invention, it will be necessary to require plain "white" paper areas on every check, on which the specimen signature is to be written. It is believed, however, that simple photoelectric means may be provided to "buck out" the check background values from the vidicon output signals, thus assuring that the "quantity" referred to above is substantially constant from check to check. The provision of such means is considered to constitute a part of the present invention.

Fortunately, however, comparator 62, the structure and operation of which constitutes an important feature of the present invention, has a tendency to compensate for such

background variations. Thus, it is expected that the system disclosed herein will be operative to attain the purpose of the invention without the use of any such background bucking or eliminating photoelectric means.

Since, as seen in Fig. 12, deflection voltage generator 316 causes the writing beam of transformer storage tube 340 to move in synchronism with the scanning beams of vidicons 280 and 282, allowing for slight phase delays due to calculation time; and since the output signal of half-log generator 36 is applied directly to input terminal 342 of transformer storage tube 340, it will be understood that a digital version of said logarithmic function of the Fourier spectrum of specimen signature 12 (sometimes called the "basic compound function" herein) will be written on the information storage electrode of transformer storage tube 340 whenever storage tube writing deflection voltage generator 316 executes its raster cycle, it being understood that storage writing tube deflection voltage generator 316, like vidicon beam deflection voltage generator 310, executes but one raster scan when triggered.

Transformer storage tube 340 is of the same type as decoder storage tube 120 of Fig. 9.

Transformer storage tube 340 produces its output signals at terminal 12R1, and receives erase signals at terminal 12R2 from terminal 9R6, the erase signal produced at terminal 9R6 being explained hereinabove.

Yet further, transformer storage tube 340 receives its reading beam sweep signals from terminals 12R3 and 12R4, through suitable amplifiers 156 and 158, all as explained hereinabove.

Referring now to Figs. 14A, 14B, 14C, 15, 16A, 16B, 17, 18, 19, 20, and 21 as a group, the operation of the devices for executing the formulae of Figs. 5 through 7 will now be described in detail.

Referring to Fig. 14A, there is shown a cathode ray analog-to-pulse count converter 346 of well-known type. As is well-known, converters of this type consist of a cathode ray tube 348, and a photosensor 350 juxtaposed to the face of cathode ray tube 348, and contained in a container 352 for excluding ambient light.

Adhered to the face of cathode ray tube 348 is a mask 354 (Fig. 14B). Mask 354 is opaque but for a plurality of slits 356 the lengths of which are proportioned as shown in Fig. 14B.

Successive R_Y signals are received at terminal 14AT1, as the scanning of the reading beam of decoder storage tube 120 goes forward.

Since terminal 14AT1 is directly connected to the upper vertical deflection plate of cathode ray tube 348, it will be seen that the scanning beam of that cathode ray tube is raised upward in proportion to the magnitude of the pixel intensity signal existing on terminal 14AT1.

The horizontal deflection plates of cathode ray tube 348 are connected to a horizontal sweep generator 358, which is triggered to sweep the scanning beam across the full width of the array of elements 356 whenever sweep generator 358 is triggered by a pixel time marker signal from pixel time marker 198 of Fig. 9, via line 9R2-14AL1.

As the sweep beam of cathode ray tube 348 sweeps across the screen thereof, it produces light pulses through mask 354, the number of light pulses being a digitized function of the amplitude of the signal at 14AT1.

Since, however, the successively occurring signals at terminal 14AT1 are the successive intensity or grey scale values of the pixels stored on the image storage electrode of decoder storage tube 120, it will be seen that the successive pulse counts produced on lead 360 by photosensor 350 are directly related to the amplitudes of the successive R_y signals received at terminal 14AT1.

The R_y signals (see Figs. 5 and 6) are analog signals proportional to the magnitudes of the intensity or grey scale values of the successive pixels stored on the image storage electode of decoder storage tube 120.

Put differently, the R_y signals are proportional in magnitude to the intensities of the successive pixel values of the basic compound function of the reference signature stored on the image storage electrode of decoder storage tube 120.

Similarly, the S_y signals occurring at terminal 12R1 as the reading beam of transformer storage tube 340 scans its information storage electrode are proportional in magnitude to the successive pixels of the basic compound function of the specimen signature which is stored on the information storage electrode of transformer storage tube 340 (Fig. 12).

Referring again to Fig. 14A, it will be seen that the circuit of that figure further comprises a gate 362. Input terminal 360 of gate 362 carries the pulse count signals from photosensor 350. The other terminal of gate 362 receives first line scan time marker signals from first line scan time marker signal generator 194 of Fig. 9 via line 9R3-14AT2.

Gate 362 thus functions to prevent the occurence of pulse count signals from input terminal 360 on output terminal 364 thereof, except during each initial scan of the horizontal lines of pixels stored on the image storage electrode of decoder storage tube 120. The signals at terminal 14AR1 are pulse-count-coded R_y signals.

Referring now to Fig. 14C, it will be seen that this figure consists entirely of a rectangle 366 having four leads corresponding in location to the four leads of Fig. 14A. It is to be understood that the circuitry represented by rectangle 366 of Fig. 14C is substantially identical to the circuitry of Fig. 14A.

It will also be seen that the pixel time marker signals from pixel time marker generator 198 of Fig. 9 are received on terminal 14CL1, and that the first line scan time marker signals from first line scan time marker generator 194 of Fig. 9 are received by the circuit of rectangle 366 on terminal 14CT2.

Similarly, it will be seen that the abovedescribed S_y signals are received on terminal 14CT1.

Thus, it will be understood that the output signals occurring on terminal 14CR1 are the pulse-count form of the S_y signals.

Referring now to Fig. 15, it will be seen that the circuit of that figure comprises a delay circuit 368, a gate circuit 370, a binary counter 372, a digital-to-analog converter 374, and an analog divider circuit 376 for dividing the analog output of digital-to-analog converter 374 by a constant, viz., 128.

Delay circuit 368 is of well-known type, and serves to slightly delay the S_y pulses, thereby interdigitating them with the R_y pulses.

Gate 370 is an OR gate of well-known type, and serves to channel both the R_y pulses and S_y pulses into the pulse input of binary counter 372. Thus, during the initial sweep of corresponding horizontal pixel rows of storage tube 120 and storage tube 340, the pulses accumulated in binary counter 372 are proportional to the sum of the sums of the stored S_y magnitudes and the stored R_y magnitudes, i.e., proportional to the numerator of the formula of Fig. 6.

As will be evident from Fig. 15 to those having ordinary skill in the art, the parallel stage output leads of binary counter 372 are so connected to corresponding terminals of digital-to-analog converter 374 that the analog output signal on terminal 379 thereof is proportional to the magnitude of the count stored at any time in binary counter 372.

Binary counters of a type suitable for use as binary counter 372 and converters of a type suitable for use as converter 374 are both well-known to those having ordinary skill in the art, and can be supplied by such without the exercise of invention.

The operational amplifier circuit 376 is of a type well-known to those having ordinary skill in the art, and the proper selection of resistors 380 and 382 to result in dividing the input quantity at terminal 378 by 128 is within the scope of those having ordinary skill in the art without the exercise of invention (See, for instance, Designing With Operational Amplifiers, by Jerald G. Graeme, McGraw-Hill Book Company, 1977, Chapter 7).

Thus, it will be seen that the analog quantity represented at terminal 15R1 of Fig. 15 is the solution, for each full initial horizontal scan of the reading beams of storage tubes 120 and 340, of the equation of Fig. 6, viz., the analog quantity corresponding to U_x.

At the end of each initial scan line binary counter 372 is cleared by a pulse signal generated by RC network 384 in response to the commencement of the second line scan time marker signal generated by second line scan time marker generator 196 of Fig. 9. This pulse produced by RC network 384 is applied to clear input terminal of binary counter 372 via lead 386.

Referring now to Fig. 16A, it will be seen that this figure consists of an operational amplifier difference circuit of well-known type (See the above-cited Graeme text, Fig. 7.2), to the inputs of which are supplied the above-described U_x and R_y signals. As will be evident to those having ordinary skill in the art, operational amplifier difference circuit 390 produces at terminal 16AR1 an analog signal proportional to the quantity R_y-U_x.

Referring to Fig. 16B, it will be seen that the circuit of this figure consists of an operational amplifier summing circuit 392 to the input terminals of which are applied the above-described U_x and S_y signals, respectively. Operational amplifier summing circuit 392 is substantially identical to operational amplifier summing circuit 390.

Thus, it will be seen that an analog signal proportional to S_y-U_x is produced at terminal 16BR1. The selection of suitable resistance values for these operational amplifier summing circuits will be done by those having ordinary skill in the art without the exercise of invention, or engaging undue experimentation.

Referring now to Fig. 17, there is shown a circuit comprising an analog multiplier 398.

Many high speed analog multipliers suitable for use as multiplier 398 are to be found in the prior art by those having ordinary skill therein. Among such prior art high speed analog multipliers are the multiplier tube arrangements of United States Patent No. 2,993,645, issued to William J. Spaven on July 25, 1961. Another suitable high speed analog multiplier for use as multiplier 398 is described in an article entitled "Wide-Band Analog Function Multiplier", at pages 160 through 163 of the February, 1955, edition of Electronics magazine. Other high speed analog multipliers based on other technologies are also available in the prior art, e.g., the high-frequency CCD adder and multiplier of United States Patent No. 4,032,767, issued to Isaac Lagnado on June 28, 1977.

Interfacing circuits for adapting the selected one of the available prior art high speed analog multipliers for use in the circuit of the preferred embodiment will be provided by those having ordinary skill in the art without the exercise of invention, and are assumed to be a part of the multiplier circuit indicated by the rectangle 398 in Fig. 17.

As also seen in Fig. 17, the multiplicand and multiplier input signals to multiplier 398 are the 16AR1 and 16BR1 signals, respectively, which, as taught, hereinabove, are the (R_y-U_x) and (S_y-U_x) signals, which are the two factors in the numerator of the equation of Fig. 5.

As explained hereinabove, each of these signals consists of a train of rectangular pulses, the amplitudes of the successive rectangular pulses at terminal 17L1 being proportional

to successive values of (R_y-U_x), and the amplitudes of the successive pulses at terminal 17L2 being proportional to successive values of (S_y-U_x). Further, the rectangular, amplitude-varying pulse signals which occur simultaneously on terminals 17L1 and 17L2 correspond in time to simultaneously scanned pairs of pixels on the photocathodes of vidicons 280 and 282 (Fig. 12).

The multiplicand and multiplier pulse signals on terminals 17L1 and 17L2 are applied to corresponding inputs of gates 400 and 402, respectively. The other input terminal of each gate 400, 402 is supplied with the second line scan time marker signal generated by second line scan time marker signal generator 196 of Fig. 9. Thus, the multiplicand and multiplier input signals are supplied to multiplier 398 only during the second scanning of each raster line by the reading beam of decoder storage tube 120.

Thus, it will be seen that successive rectangular, or substantially rectangular, pulses occur at the output terminal 404 of multiplier 398, the amplitude of each such pulse being proportional to the product of the amplitudes of the corresponding input multiplier and multiplicand pulses.

Gate 406 serves to restrict the time of application of the successive pulses on output lead 404 of multiplier 398 to input lead 408 of analog-to-digital converter 410 to interva[ls] during which the pulses on output terminal 404 have achieved their full amplitude, and have not yet begun to decline in amplitude.

To this end, the pixel time marker signal generated by pixel time marker signal generator 198 of Fig. 9 is applied to a pulse shaping network 412, which, when triggered by the pixel time marker signal, produces a rectangular pulse

shorter in duration than the rectangular pulses on multiplier output terminal 404, and existing only when those rectangular pulses have reached their maximum amplitude, and not yet begun to decline in amplitude.

Thus, the input signal pulses at the input terminal 408 of analog-to-digital converter 410 are all substantially rectangular, and their amplitudes are proportional to successive (S_y-U_x) (R_y-U_x).

As will be understood from the above, then, analog-to-digital converter 410 converts successive pulse amplitudes, corresponding to successive ones of the products found in the numerator of the formula of Fig. 5, to binary signals on its parallel output leads 414.

The entry of the successive binary signals on parallel output leads 414 into binary adder 416 is controlled by successive pulses produced by RC network 418 and delay circuit 420, which are so constructed and arranged, in the manner well-known to those having ordinary skill in the art, as to cause these binary adder insert pulses to occur during the latter part of the "open time" of gate 406.

The binary sum existing at any time in binary adder 416 is represented on its parallel output connections 424.

As also seen in Fig. 17, digital-to-analog converter 428 serves to convert the binary sum signals on parallel output leads 424 to an analog signal appearing on its output terminal 430.

As also seen in Fig. 17, the first line scan time marker signal on terminal 9R3 of Fig. 9 is supplied to RC network 432, which produces a pulse at the end of every first line

scan time. This pulse supplied by RC network 432 is applied to the clear terminal of binary adder 416, and thus serves to clear binary adder 416 just before the beginning of each second line scan time.

Suitable circuits for converters 410 and 428, and for binary adder 416, are well-known to those having ordinary skill in the art, being available, for instance, as widely available, standardized integrated circuit chips, and thus will not be described in detail herein. Similarly, suitable interfacing circuits for matching the impedances and signal levels of vacuum tube elements of the present system to integrated circuit elements are well-known to those having ordinary skill in the art, and will not be discussed herein.

As will further be seen in Fig. 17, a gate 436 is provided to assure that the analog signal appearing at converter terminal 430 appears on figure terminal 17R1 only after each line of the output raster of decoder storage tube 120 (and, of course, decoder storage tube 340) has been twice scanned by its (their) reading beam(s). Gate 436 is opened in response to the occurrence of the end of the second line scan time marker signal on terminal 9R4. This signal is applied to RC network 438, which produces a pulse when this signal (9R4) ceases. This output pulse from RC network 438 is slightly delayed in time by delay circuit 440, and continues to exist during an interval determined by monostable multivibrator 442, in the well-known manner.

As will now be evident to those having ordinary skill in the art, the circuit of Fig. 17 produces at terminal 17R1 a series of particular pulse signals the amplitudes of which are equal to the successive values of the numerator of the formula of Fig. 5.

Referring now to Fig. 18, there is shown a circuit comprising two squarers 448, 450, which may be of the same type as squarers 324 and 326 of the circuit of Fig. 12.

The circuit of Fig. 18 further comprises a pair of analog-to-digital converters 452, 454; a pair of binary adders 456, 458, and a pair of digital-to-analog converters 460, 462.

Analog-to-digital converters 452 and 454 may be of the same type as analog-to-digital converter 410 of Fig. 17.

Binary adders 456 and 458 may be of the same type as binary adder 416 of Fig. 17.

Digital-to-analog converters 460 and 462 may be of the same type as the digital-to-analog converter 428 of Fig. 17.

The circuit of Fig. 18 further comprises a pair of gates 464, 466 which operate analogously to gate 406 of Fig. 17, i.e., which permit the analog output signals of squarers 448 and 450 to reach their corresponding analog-to-digital converters 452, 454 only when the input 16AR1 and 16BR1 signals have assumed their maximum values, and have not yet begun to decline.

Pulse shaper 468 is similar to and operates analogously to pulse shaper 412 of Fig. 17.

Further, RC network 470 and delay circuit 472 operate to control the insertion of digital data from analog-to-digital converters 452, 454 into their corresponding binary adders 456, 458, in a manner similar to the function of RC network 418 and delay circuit 420 of Fig. 17.

As will also be seen in Fig. 18, binary adders 456 and 458 are cleared by the same 17B1 signal which also clears binary adder 416 of Fig. 17.

The circuit of Fig. 18 further comprises a pair of gates 476, 478 which function analogously to gate 436 of Fig. 17, "opening" to permit signals on their respective output terminals 18R1, 18R2 at the same time that gate 436 of Fig. 17 "opens" to permit output signals on its output terminal 17R1.

Thus, it will be understood by those having ordinary skill in the art, informed by the present disclosure, that the circuit of Fig. 18 serves to produce at its output terminals 18R1, 18R2 signals which are proportional in amplitude to the respective summed squared quantities found in the denominator of the formula of Fig. 5.

Referring now to Fig. 19, there is shown a circuit comprising an analog multiplier 480 and a square root function generator 482.

Analog multiplier 480 may be an analog multiplier of the same type used as analog multiplier 398 of the circuit of Fig. 17.

Alternatively, analog multiplier 480, and analog multiplier 398 as well, may be operational amplifier circuits of the kind discussed in Article 7.4 of the above-cited Graeme text, <u>Designing With Operational Amplifiers.</u>

Square root function generator 482 of Fig. 19 may be modifications of any one of the devices suggested for use as the half-log function generator 336 of Fig. 12. i.e., square root function generator 482 may be one of the well-known

electronic arbitrary square-root function generators, such as those of the above-cited United States Patents 2,907,888 and 3,037,123. Alternatively, function generator 482 may be a square-root device of the type disclosed in United States Patent No. 2,461,667, issued to David E. Sunstein on February 15, 1949. Where such cathode ray tube arbitrary function generators are used, their function masks, or the like, will of course necessarily be configured in accordance with the square root function.

Alternatively, a special beam deflection tube of the OK-329 type, but with square-root-figured beam apertures, or a square-root extracting operational amplifier circuit of the kind discussed in Article 7.4 of the above-cited Graeme text, may be used as square root function generator 482.

As further seen in Fig. 19, the output terminal 484 of square root function generator 482 is directly connected to one of the two input terminals of gate 486.

As further seen in Fig. 19, the "gate opening" signal on the other terminal 494 of gate 486 is provided by the 9R4 signal, conditioned by an RC network 488, a delay circuit 490, and a monostable multivibrator circuit 492. These three circuits, i.e., 488, 490, and 492, are substantially similar to corresponding circuits 438, 440, and 442, of Fig. 17.

Thus, it will be seen by those having ordinary skill in the art, informed by the present disclosure, that output signals appear on terminal 19R1 during the same interval during which corresponding output signals appear on terminal 17R1. [G.15]

As will also be obvious to those having ordinary skill in the art, informed by the present disclosure, the output

signals appearing on terminal 19R1 will be analog signals the amplitude of which is proportional to the denominator of the formula of Fig. 5, for each successive double scan of a particular raster line by the reading beams of storage tubes 120 and 340.

Referring now to Fig. 20, there is shown a circuit comprising an analog divider 500, an analog-to-digital converter 502, a cumulative multiplier 504, and a digital-to-analog converter 506.

Divider 500 may, for example, be a cathode ray tube analog divider of the kind disclosed in the above-cited Spaven United States Patent No. 2,993,645. Alternatively, divider 500 may be an operational amplifier divider circuit of the kind discussed in section 7.4 of the above-cited Graeme text.

Analog-to-digital converter 502 may be of the same type as used for analog-to-digital converter 410 of the circuit of Fig. 17, and digital-to-analog converter 506 may be of the same type used for digital-to-analog converter 428 of the circuit of Fig. 17.

Cumulative multiplier 504 may be an integrated circuit cumulative multiplier of the kind found, for example, in current model calculators and the like, and may be either a custom integrated circuit or a portion of an integrated calculator circuit, both of which are currently sold by integrated circuit manufacturers, which integrated circuit manufacturers also provide suitable application data for adapting such calculator integrated circuits to specific, dedicated uses, such as the use contemplated in Fig. 20.

cumulative multiplier 504 may be arranged by those having ordinary skill in the art, without the exercise of invention, to be cleared by the 9R5 signal.

Further, the entry signal for entering successive digital values into cumulative multiplier 504 is provided at terminal 507 of cumulative multiplier 504 by the 9R4 signal, conditioned by RC circuit 508 and delay circuit 510. RC circuit 508 is substantially similar to RC circuit 438 of Fig. 17, while the delay provided by delay circuit 510 is longer than the delay provided by delay circuit 440 of Fig. 17, whereby the pulses occurring at enter signal terminal 507 of cumulative multiplier 504 will be so timed that the digital signals on the parallel output lines of analog-to-digital converter 502 will be "settled down" before the corresponding entry pulse at terminal 507 occurs.

Delay circuit 510, like the other pulse delay circuits used herein, may be selected from among available expedients, e.g., active devices such as monostable multivibrators with output pulse shapers, or passive devices, such as short lumped-constant delay lines, without the exercise of invention or engaging in undue experimentation.

Recalling now that signal 19R1 is proportional in amplitude to the denominator of the formula of Fig. 5, and that signal 17R1 is proportional in amplitude to the numerator of the equation of Fig. 5, it will be understood by those having ordinary skill in the art that the analog signal on output terminal 514 of divider 500, when it exists, i.e., after the double scanning of each line of the reading raster of storage tubes 120 and 340, will be proportional to the magnitude of the line correlation coefficient C_x.

It will then be evident to those having ordinary skill in the art, informed by the present disclosure, that successive signals appearing on parallel output lines 516 of analog-to-digital converter 502 are digital equivalents of the successive magnitudes of C_x.

Since, as explained above, cumulative multiplier 504 accumulates the running product of all of the C_x values for each line throughout each complete scanning of the reading beams of the two storage tubes 120, 340, it will be evident from the formula of Fig. 7 that at the end of each 64X64 raster scan, in synchronism, of the reading beams of storage tubes 120 and 340, the quantity digitally represented on cumulative multiplier output lines 518 will be the full signature correlation coefficient C_s of Fig. 7.

It will also be evident that by the action of digital-to-analog converter 506 an analog signal proportional to the magnitude of full signature correlation coefficient C_s will at the same time be presented on terminal 20R1.

Referring now to Fig. 21, there is shown the simplest possib circuit of rejection indicator 66 (Fig. 4).

Referring to Fig. 21, it will be seen that this rejection indicator circuit comprises an operational amplifier 520 and a potentiometer 522.

The C_s or complete signature correlation coefficient C_s is impressed on the upper or positive terminal of operational amplifier 520 via link 21L1-20R1.

A suitable direct current voltage is maintained across potentiometer 522 by power supply means of well-known type which need not be described here.

The voltage on the lower or negative input terminal 526 of operational amplifier 520 is supplied by potentiometer 522 and its associated power supply, and can be varied or adjusted by motion of the slider 524 of potentiometer 522 in the well-known manner.

As will be obvious to those having ordinary skill in the art, a signal will be produced at output terminal 525 of operational amplifier 520 only when the C_s signal on operational amplifier input terminal 528 exceeds the threshold signal on input terminal 526 of operational amplifier 520.

In other words, rejection indicator circuit 66, as shown in Fig. 21, provides an output signal only when the coefficient C_s corresponding to a particular signature comparison is greater than the preset threshold, and thus the check or other document being examined by the device of the present embodiment is verified or accepted.

It is contemplated that within the scope of the present invention other more elaborate rejection indicator circuits may be employed, such as adaptive or learning circuits which automatically set the threshold potential on input terminal 526 of operational amplifier 520 in accordance, for instance, with the number of checks rejected in the previous hour of check verifying operation.

Many other check rejection indicator circuit variants will be obvious to those having ordinary skill in the art, and will be supplied for use in the system of the preferred embodiment herein without the exercise of invention.

As may be seen from Fig. 4, the output signal of rejection indicator 66, which is the signal on terminal 21R1, is preferably fed to a document rejector 68, which is part of

conventional check handling apparatus capable of segregating certain checks from others being processed.

Such paper handling and rejection apparatus, however, is not part of the present invention, and will not be discussed herein.

Referring now to Fig. 22, there is shown the optical pickup unit 22 for imaging reference signature from signature cards.

As may be seen by comparison with Fig. 11, the device of Fig. 22 differs from that of Fig. 11 principally in that the document carries 540, 542, 544 of belt 548 are shorter in length than the corresponding document carriers 72, 74, 76 of belt 70 of Fig. 11. This is because document carriers 540, 542, and 544 of the optical pickup unit 26 of Fig. 22 are adapted to carry signature cards, rather than checks.

Additionally, belt 548 is preferably adapted for hand feeding of signature cards, since each cryptograph transparency maker 24 will probably deal with far fewer signature cards, than each check reader will deal with checks.

With this exception, it can be seen by comparison of Fig. 11 and 22 that the device of Fig. 22 is substantially identical to the device of Fig. 11.Thus, when the signature card in any document carrier 540, 542, or 544 is in proper registration with the lens system 550 of optical pickup unit 26, the beam splitters 552 and 554 will be reflecting upwardly (in Fig. 22) two substantially identical reference signature images 556 and 558.

Referring now to Fig. 23, there is shown the belt halt signal generator 560 of reference signature optical pickup unit 26.

Comparing Fig. 23 and Fig. 8, it will be seen that belt halt signal generator 560 is substantially identical to belt halt signal generator 90 of cryptograph optical pickup unit 38 (Fig. 4).

Light source 562, photosensor 564, monostable multivibrator 566, and RC network 568, are substantially identical to the corresponding elements 94, 96, 98, 104 of Fig. 8.

Thus, it may be seen that the belt halt signal generator 560 of Fig. 23 serves to produce at terminal 23R1 a belt halt signal whenever belt 548 halts, just as belt halt signal generator 90 of Fig. 8 produces a belt halt signal at terminal 8R1 whenever belt 70 halts.

Referring to Fig. 24, there is shown the circuit of reference signature transformer 28 (Fig. 3). It will be seen that Fourier cosine transformer 570, Fourier sine transformer 572, beam splitters 574 and 576, pixel averages 578 and 590, vidicons 592 and 594, vidicon deflection voltage generator 596, squarers 598 and 600, summer 602, half-log function generator 604, delay circuit 606, storage tube writing deflection voltage generator 608, and storage tube 610, all are substantially identical to the corresponding parts 268, 270, 272, 274, 276, 278, 280, 282, 310, 324, 326, 332, 336, 314, 316, and 340 of the circuit of Fig. 12.

Wobble generator 612 of the circuit of Fig. 24 is also substantially identical to wobble generator 318 of the circuit of Fig. 12.

Thus, it may be seen that the basic compound function of the reference signature on each signature card as stored on the information storage electrode of storage tube 610 will be

the same basic compound function which the circuit of Fig. 12 serves to generate from the specimen signatures on checks, and store on the information storage electrode of storage tube 340 (Fig. 12).

It will be further understood that this substantial identity of the specimen signature optical pickup unit and transformer 40, 60 (Fig. 4) and the reference signature optical pickup unit and transformer 26, 28 (Fig. 3) is not at all fortuitous, but is intended, in accordance with the principles of the present invention, so that the same basic compound function of the reference signature produced by optical pickup unit 25 and transformer 28 will be substantially the identical function of the specimen signatures on checks produced by optical pickup unit 40 and transformer 60.

It will be noted, however, that storage tube writing deflection voltage generator 608 is unpossessed of a signal lead corresponding to signal lead 12T1 of storage tube writing deflection voltage generator 316. This is because the reading deflection signal generators for the encryptor storage tube of Fig. 25 are triggered or started in a manner different from the triggering or starting of the corresponding reading deflection signal generators 150, 152 of Fig. 9, for reasons hereinafter explained in connection with Fig. 25.

Further, it will be noted that vidicon deflection voltage generator 596 of Fig. 24 is provided with an output connection including monostable multivibrator 614 and RC circuit 616, the function of which will be explained hereinafter in connection with the reference signature transform encryptor circuit of Fig. 25.

Further considering Fig. 24, it will be noted that storage tube 610 is provided with an output information signal terminal 24R1, reading beam sweep connections 24R3 and 24R4, and an erase signal connection 24R2.

Referring now to Fig. 25, there is shown the circuit of reference signature transform encrypter 30 (Fig. 3).

Comparing Fig. 25 with Fig. 9, it will be seen that there are a number of subcircuits common to these two circuits.

Thus, deflection signal generators 620, 622 and 624 of Fig. 25 are substantially identical to the corresponding deflection signal generators 170, 172, and 174 of Fig. 9.

Similarly, storage tube 626 of Fig. 25, and its related auxiliary circuitry, is substantially identical to storage tube 120 of Fig. 9, and its related auxiliary circuitry, all represented in each case by the corresponding storage tube rectangles in Fig. 25 and 9.

Also, vertical reading deflection voltage amplifier 628 of Fig. 25 is substantially identical to vertical reading deflection voltage amplifier 184 of Fig. 9.

Yet further, the storage tube reading deflection signal generators 630 and 632 of Fig. 25 are substantially identical to the storage tube reading deflection signal generators 150 and 152 of Fig. 9.

Also, writing beam deflection voltage generator 634 and wobble generator 636 of Fig. 25 are substantially identical to writing beam deflection voltage generator 124 and wobble generator 126 of Fig. 9.

The circuit of Fig. 25 differs from that of Fig. 9 in that a plurality of push-button pulse generator circuits 638, 640, 642 are provided, whereby the mode of encoding of any reference signature may be selected in accordance with the account number appearing on the signature card.

Each push-button pulse generator 638, 640, 642 is connected to provide a triggering impulse to an associated monostable multi-vibrator 644, 646, 648, whereby to open its associated gate 650, 652, 654; gates 650, 652, and 654 being substantially identical to the corresponding gates 186, 188, and 190 of Fig. 9.

In addition to thus connecting its associated deflection signal generator with vertical reading deflection voltage amplifier 628, the depression of any one of the push-buttons 638, 640, 642 also acts through OR-gate 660, short period monostable multi-vibrator 662, and RC pulse-generating circuit 664, to trigger storage tube reading deflection signal generators 630 and 632 into action.

Thus, whenever one push-button 638, 640, 642 is depressed, the basic compound function of the reference signatures stored in storage tube 626 is read out, correspondingly encrypted, to cryptograph display unit 32 of Fig. 26, over link 25R1-26L1.

Cryptograph display unit 32 of Fig. 26 is a suitable video display monitor, the raster voltages of which are provided by storage tube reading deflection signal generators 630, 632 via links 25R3-26L2 and 25R4-26L3.

It is to be noted at this point that deflection signal generators 630 and 632, being of the 64X64, double line scan type defined hereinabove, could be replaced by corresponding

single line scan deflection signal generators for the purposes of the reference signature transform encryptor of Fig. 25.

As further seen in Fig. 25, a gate 670, cascaded with a monostable multivibrator 672 and a pulse shaper 674 is connected to both reading deflection signal generator 630 and reading deflection signal generator 632.

Thus, an erase signal is supplied to the auxiliary erase switching circuit of encryptor storage tube 626, and also is supplied to the auxiliary erase switching circuit of transformer storage tube 610 of Fig. 24 via link 25R2-24R2. By this means, both storage tube 626 and storage tube 610 are automatically erased shortly after the basic compound function of the reference signature stored in encryptor storage tube 626 is transferred to cryptograph display unit 32 (Fig. 26) and encrypted during that transfer.

As also seen from Fig. 25, the signal provided at terminal 24B1 of Fig. 24 is applied via link 25L2-24B1 to the triggering input of writing beam deflection voltage generator 634, thus commencing the transfer of the basic compound function of the reference signature on the reference signature card in document carrier 542 from storage tube 610 to storage tube 626 as soon as that basic compound function is stored in storage tube 610.

Referring to Fig. 26, it will be noted that a wobble generator 680 is provided to modulate the vertical deflection signals (amplified) from storage tube reading deflection signal generator 632. Wobble generator 680 is provided for the same reason that wobble generator 126 of Fig. 9 is provided, and the reason for which the other wobble generators shown and described herein are provided, as set out above in connection with wobble generator 126 in the description of Fig. 9.

As also shown in Fig. 26, the image 682 of the basic compound function of the reference signature shown on display unit 132 is imaged upon the optics of transparency camera 34, whereby transparency camera 34 can produce a corresponding cryptograph transparency, and an electrical connection 684 is provided whereby the basic compound function image is generated on the display screen of cryptograph display unit 32, transparency camera 34 is triggered, its shutter operated, and then its film advance operated.

The term "signature verification" as used herein denotes the comparison of properties of a particular signature with comparison data representing the same properties of a reference signature in order to determine whether said particular signature shares those properties with said reference signature. (In the simplest case, i.e., direct human visual comparison of a check signature with a signature card signature, the "comparison data" is the reference signature itself.)

The term "signature authentication" as used herein denotes a testing operation for the determination of whether the comparison data to be used in verifying a particular signature was derived from a reference signature of an authorized user of the document bearing the particular signature.

The term "reference signature" as used herein denotes a signature recorded for possible future reference, e.g., a depositor's signature on a bank signature card, or the signature on a security clearance data file card of a person cleared for admission to restricted access premises.

The terms "specimen of said reference signature" and the like as used herein denote a signature later executed by the writer of a corresponding reference signature with the

intent to execute his signature in the format of that reference signature. (This definition recognizes that many persons consciously adopt two or more signature formats, e.g., one format for social transactions and another format for financial transactions. Thus, if an individual has written his financial signature on a bank signature card, his later-written financial signature, executed with the intent to execute his financial signature, will be "a specimen of said reference signature" in accordance with this definition, taking the financial signature on the bank signature card as the "reference signature"; but his social signature, executed with whatever intent, will not be "a specimen of said reference signature". Further, this definition (financial) also recognizes that for sometimes subconscious or unappreciated reasons individuals change their signatures at certain times of life, gradually or precipitously. In accordance with this definition, a signature of an individual executed after such a signature change and manifesting a discernible change or changes in handwriting style or format is not "a specimen" of a reference signature executed by that individual before that change.)

The term "authorized user" as that term is used herein refers to a document (e.g., a bank check, a credit card, or an identity card) and denotes any person entitled to utilize that document. Thus, a depositor in a bank checking account whose signature appears on a corresponding signature card is an authorized user of checks (documents) drawn on that account. Similarly, the rightful holder of a credit card is in most cases the authorized user of that credit card. Further, the issue of an identification card for admission to security restricted premises is in most cases the authorized user of that identity card.

The term "document" is used herein in its broadest acceptation to denote anything which carries or can carry data or other information in any form of representation or notation. Thus, the term "document" as used herein includes within its embrace but is not limited to any body of material substance, such as a card or paper, an envelope, a carton, a container, a book or pamphlet, a plate, a credit card, a debit card, an identification card, a passport, a national identity card, or an identification badge, having on it a representation of any numerical or linguistic data or any other patter.
[G.76]

The term "cryptograph" is used herein in its broadest acceptation to denote any pattern or indicium whether symbolic or graphic having a hidden or not directly discernible significance, and thus embraces all of the concepts and things embraced by the term "cryptoeidograph". Thus, the term "cryptograph" as used herein embraces not only modified writings having hidden significance but also embraces modifide or distorted patterns having hidden significance, such as a hologram of a handwritten signature or a mosaical anamorphosis of a handwritten signature as typifed in Fig. 9 of United States Patent No. 3,676,000 of Mayer and Dobbins. For example, the term "cryptograph" as used herein embraces all of the cryptographic representations made by and used in cryptographic systems of the kind described at pages 828 through 836 of The Codebreakers, by David Kahn, published by the Macmillan Company, New York, 1967, Fourth Printing, 1968. The term "cryptograph" as used herein also denotes any encrypted cryptograph. Thus, not only is the Fourier spectrum of a handwritten signature produced by a Fourier transformer a cryptograph, but a mosaical anamorphosis of that Fourier spectrum is also a cryptograph, as the term "cryptograph" is used herein. In this example, the original handwritten signature can be thought of as "superencrypted" or "superenciphered".

The term "cryptographic" as used herein denotes anything related to or used in the making or interpreting of cryptographs or having the properties of a cryptograph as that term is described herein.

The term "encrypt" as used herein denotes the making of a cryptograph, as the term cryptograph is defined herein. Thus, the term "encrypt" as used herein denotes the making of any cipher from any unmodified, i.e., clear or plain, text or other writing having apparent significance, and the making of any cryptoeidograph of an unmodified, plain, or clear pattern having apparent significance.

The term "decrypt" as used herein is used antonymously with respect to the term "encrypt".

Thus, the term "decrypt" as used herein denotes the recovering of an unmodified, clear, or plain writing or other text having apparent significance from a corresponding cipher or other symbolic cryptograph, and also denotes the recovering of an unmodified, clear, or plain pattern having apparent significance from a corresponding crytoeidographic pattern.

The term "encryption" as used herein denotes the process of encrypting.

The term "decryption" as used herein denotes the process of decrypting.

The term "indicium" is used herein in the conventional sense, and thus embraces any pattern composed of a plurality of indicia.

The term "pattern" is used herein in its broadest acceptation to denote anything which is to be or is fit to be copied or imitated.

The noun "representation" is used herein in its broadest acceptation and thus includes but is not limited to cryptographic representations and reproductions of encrypted or unencrypted patterns in other forms or media. Thus, the noun "representation" as used herein embraces but is not limited to digital images, mosaics, both regular and irregular, half-tone prints, xeroprints, images produced by light fiber bundles, video recordings, and anamorphoses, including mosaical anamorphoses such as are produced by "fly's eye" lenses, of both encrypted and unencrypted patterns. For example, the noun "representation" as used herein embraces superimposed recordings made in accordance with the teachings of United States Patent No. 2,989,595 of the gray levels and corresponding coordinates of the pixels of a digital image of the Fourier spectrum of a manuscript signature displayed as an intensity function, whether said recording is magnetic or photoelectric, and whether recorded on one or a plurality of tracks. Further, the noun "representation" as used herein also embraces light intensity distribution images, e.g., the image of an object formed by an optical projection system such as a slide projector, or the light intensity distribution pattern found in the transform plane or output plane of a Fourier optical transformer when an object to be analyzed is located in the corresponding input plane thereof.

The term "non-holographic" is used herein in its broadest acceptation to refer to any thing incapable of giving rise to a three-dimensional representation of an original object, however illuminated, or any process incapable of giving rise to such a representation when applied to a suitable thing.

For definitions of the terms "digital image", "gray level", "pixel" and related terms reference is had to pages 21 through 31 of Digital Image Processing, by Rafael C. Gonzalez and Paul Wintz, Addison-Wesley Publishing Company, Inc., 1977.

The term "function" is used herein in its broadest acceptation, to denote any magnitude so related to another magnitude that to values of the latter there correspond values of the former.

The term "compound function" is used herein in its broadest acceptation, to denote a function of a function, etc.

It will thus be seen that the objects set forth above, among those made apparent from the preceding description, are efficiently attained, and since certain changes may be made in the above constructions and the method carried out thereby or therewith without departing from the scope of the present invention it is intended that all matter contained in the above descriptions or shown in the accompanying drawings shall be interpreted as illustrative only, and not in a limiting sense.

It is particularly noted that although in the principal embodiment of the present invention shown and described herein the superencryptment of the basic compound function of the specimen and reference signatures has been keyed to a cryptokey printed on the check, and separate and apart from the account number also printed on the check, it is within the scope of the present invention to provide an additional superencryptment keyed to the account number or some portion thereof. Furthermore, it lies within the scope of the present invention to triply superencrypt the basic compound function of the reference signature and the specimen signature, i.e., to first superencrypt said basic compound functions in accordance with a single, universal superencryptment, then to additionally encrypt the already universally encrypted basic function in accordance with this second superencryptment selected in accordance with the account number appearing on the check, or some part thereof,

and thirdly to again superencrypt the already twice super-encrypted basic compound function of the specimen signature and reference signature in accordance with a different mode of encryptment keyed to a cryptokey printed on the check separate and apart from the account number.

Yet further, while in the preferred embodiment of the present invention shown and described herein the mode of encryptment selected was the recollacation or "scrambling" of the squares or elements of the basic compound signature function mosaic, it is to be understood that other modes of encryptment are contemplated in connection with the present invention, such as arbitrarily reducing the gray level, or increasing the gray level, of every pixel or element of one or more rows or columns of the basic compound signature function matrix.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.